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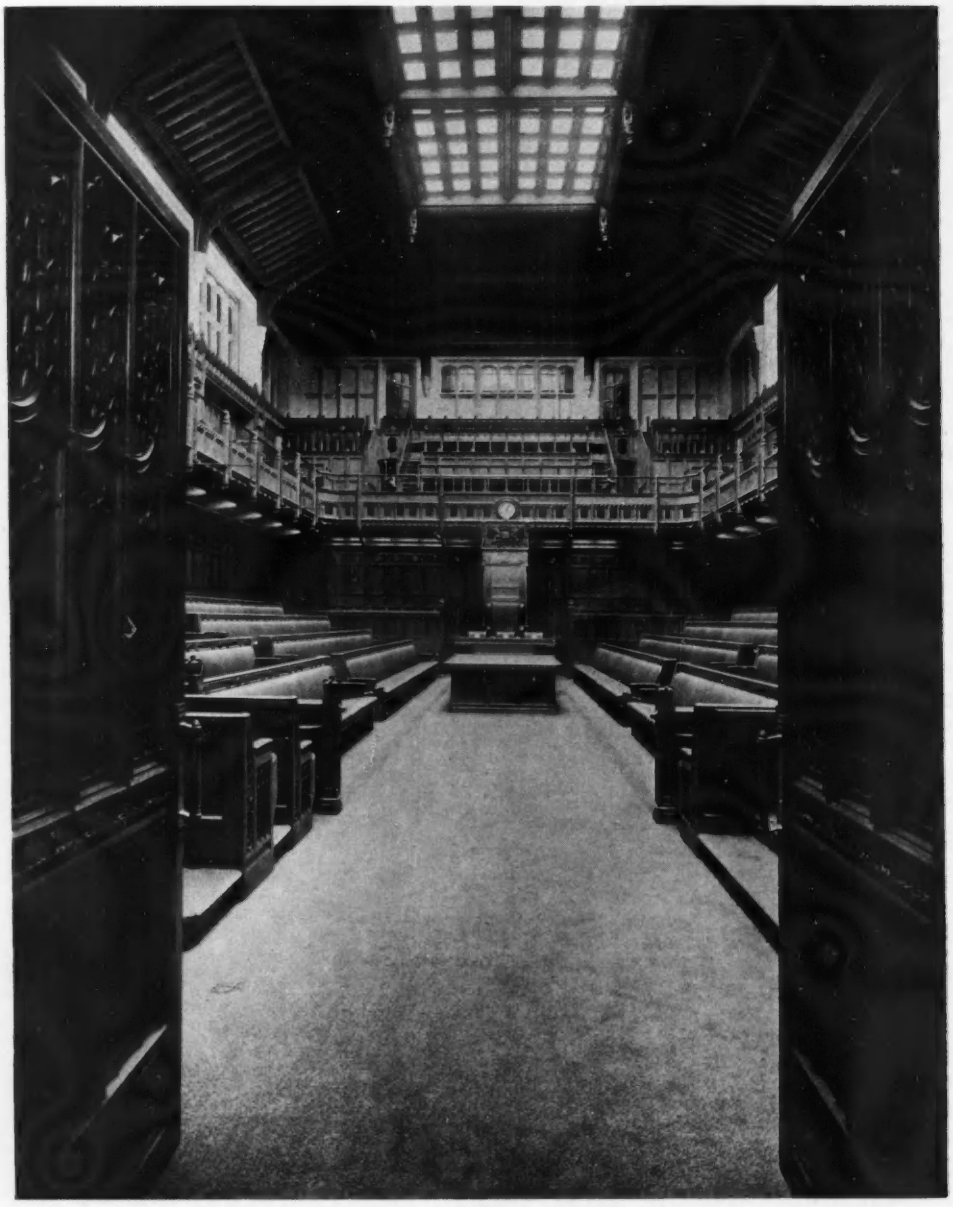

THE CHAMBER OF THE NEW HOUSE OF COMMONS.

Lighting of the New House of Commons

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This article is based on a paper read by the author to the Illuminating Engineering Society in London on November 14th, 1950. It describes the ingenuity which has had to be exercised in the difficult task of lighting the Chamber of the House of Commons, and shows how modern lighting technique can be applied to meet the most exacting architectural requirements.

INTRODUCTION.

THE old House of Commons was destroyed during an air raid in May, 1941. When plans were being prepared for the new House, considerable thought was given to the style and character which should be adopted. An opportunity had been created to depart from the form of architecture of the old building, but the decision was made nevertheless to reintroduce the late Gothic style in harmony with the rest of the Palace of Westminster.

Although the new building has been erected on the original site, skilful planning by the architect has resulted in much improvement in the amenities. These include not only the provision of two floors below the Chamber, for the accommodation of ministers' rooms, members' lounge, conference and other rooms, but also an additional floor at the top of the new House. Greater accommodation has also been provided by increasing the size of the galleries, and the total seating capacity in the entire Chamber has risen from 802 to 939.

In designing the new House, the architect has retained the character and dignity of the old House, and at the same time eliminated some of the elaborate ornamentation which was predominant. Sir Giles Gilbert Scott in his report upon the proposed new House of Commons, stated "The Gothic detail of the old Chamber was lifeless and uninteresting, and the richness was spread evenly over the whole area without relief or contrasts. It has been our endeavour to remedy this, with the result that, though still Gothic in style, the effect will be entirely different from what existed before".[1]

Every opportunity has been taken to introduce throughout the building the most modern methods for heating, ventilating, lighting and electric services generally. Extensive tests and trials were carried out before final decisions were made and reference to some of those applicable to the lighting will be mentioned in this paper.

The keynote of the lighting throughout the House, and particularly in the Chamber, is the artistic use of modern light sources. The high luminous efficiency and flexibility of colour from these sources has made possible a full development of the artistic ideas of the architect.

THE CHAMBER LIGHTING.

General Description.

The seating arrangements are similar to the original disposition with benches facing each other across the floor of the House. Specially treated English oak has been used not only for the benches, but also for the roof, which slopes from the sides of the Chamber to a middle flat portion, and for the extensive panelling of the walls above and below the gallery. The main characteristic of the panels is to form a concentration of ornamentation having horizontal bands of rich carving with contrasting plain surfaces. Against these large areas of timber, light-colour Clipsham stone has been used for the windows and masonry in the gallery. The benches are upholstered in green, and the floor is covered with carpets of mottled brown-fawn colour to tone with the oakwork, except for the middle of the floor of the House, where the carpet is green.

The Lighting Problem.

As seats are distributed over much of the floor area and the whole of the gallery, it is clear that a lighting system had to be devised which would

Fig. 1.—The Speaker's Chair

Fig. 2 (*above*).—Daylight appearance of the laylight in the Chamber.

Fig. 3 (*below*).—The laylight by night.

ensure a good level of illumination in all parts of the Chamber. Natural lighting is admitted through the windows along the east and west walls above the gallery and, during the periods when daylight could be used, the architect desired that there should be no evidence of the arrangements which had been made for artificial lighting. It was a further requirement that, as the daylight waned, the artificial lighting could be so controlled that at no time would its introduction be likely to distract a member addressing the House.

Chamber Ceiling.

The central portion of the ceiling has been made in the form of a laylight consisting of five principal panels, each of these being subdivided into thirty smaller panels. An ingenious illusion has been obtained by glazing these panels with a specially coloured glass so that when the Chamber is lit by daylight from the side windows, the whole of the roof and ceiling appear to be constructed of timber (fig. 2).

The principal source of artificial lighting is installed in the void above the ceiling, but as each of the 150 glazed panels is surrounded by a wide oak framework it was not possible to use light sources which covered more than one panel without reducing very considerably the overall efficiency. Each panel has, therefore, been treated as a separate lighting unit. Many difficulties had to be overcome before a suitable glass was found, the most important factors which had to be considered being :

1. The daylight appearance of the glazing had to bear a close resemblance to the oak roof.
2. The glazing had to be sufficiently diffusing to obscure satisfactorily the source of the light (fig. 3).

3. The light transmission factor had to be as high as possible.
4. Specular reflections in the front surface of the glass had to be avoided.
5. The material used for the glazing had to be non-inflammable and unbreakable.

After numerous tests, during which no fewer than eleven different types of glass were carefully examined, a special 3-ply glass was eventually selected. The correct colour was not obtained, however, without absorbing rather more of the light than would otherwise have occurred.

Preliminary Tests.

After a series of preliminary tests elsewhere, a decision was made to have an actual demonstration in the House of Commons, using both hot and cold cathode lamps, and for this test 120 of the total 150 panels were used, 60 being equipped with hot cathode lamps and the remaining 60 with cold cathode lamps.

These large-scale tests to determine the type of lamp to be used were made when the Chamber was little more than a shell, presenting a scene of stone and concrete with no glazing in the windows. A temporary ceiling was constructed and fixed in the position which would be ultimately occupied by the permanent ceiling so that realistic effects could be obtained.

Fig. 4.—Cold cathode units in position over the laylight of the Chamber.

All the lamps were dimmer controlled and particular attention was paid to the following points when assessing the relative merits :

Fig. 5.—General view of a cold cathode unit.

1. Comparative efficiencies.
2. Appearance of the lighted panels.
3. Ability to introduce lighting from zero to a maximum, and to dim from the maximum to blackout.
4. Maintenance problems with special reference to lamp life.

Comparison between Hot and Cold Cathode Lamps.

As can be seen by reference to Table 1, there was little to choose between the efficiencies of the two lamps.

The dimming of both systems was good, but it was generally felt that the results from the cold cathode were the better. In the hot cathode scheme, each panel was lighted by four 20 watt 2 ft. lamps, and in order to keep the gear losses as low as possible the lamps were operated in pairs with two in series. This arrangement had the disadvantage that the failure of one lamp meant that two would be extinguished. It was also in-

TABLE 1.

COMPARISON BETWEEN HOT CATHODE AND COLD CATHODE LAMPS FOR THE CEILING IN THE CHAMBER.

	Hot Cathode	Cold Cathode
Total number of fluorescent lamps in laylight	600	150
Lamp efficiency lumens/watt average throughout life ...	31	31
Approx. consumption per panel, including gear and dimmer losses (watts) ...	135	155
Average illumination at floor level at 100 hours (lumens per sq. ft.)	8	12½
Estimated number of lamps used in 10 years	2,400	150

evitable that in time a succession of lamp failures would occur, each causing the uniform brightness of the ceiling to be marred by dark patches.

Compared with the 600 lamps in the hot cathode system, the cold cathode scheme used only 150 lamps. The much longer life of the cold cathode lamps and the smaller number used reduced considerably the likely incidence of failures. In fact, it has been estimated that, since in an average year the main lighting in the Chamber may be in use for about 1,000 hours, lamp replacement should not be required for several years. After all factors had been considered the decision was made to employ cold cathode lamps for the main ceiling lighting.

Dimmer Controlled Circuits.

Since only very limited dimming is obtained when one series resistance is used to control several fluorescent lamps, it was necessary to provide a method for varying the current in individual lamps. A separate variable resistance could be used for each circuit, but in this instance it would present many practical difficulties as in the Chamber a total of 243 fluorescent lamps, including hot cathode and cold cathode types, have to be dimmed.

The fluorescent lamp circuits, described later, with the exception of that for the Speaker's chair, include a transductor (or D.C. saturable choke) for each lamp. With this arrangement many lamps can be dimmed together by using one control, such as a potentiometer, to adjust the direct current in the control windings of the transductors. This method enabled a dimmer equipment with a minimum of moving parts to be installed.

Description of Cold Cathode Scheme.

The control of the lighting had to be smooth to ensure a steady uniform increase in illumination, and although it was realised that in practice the artificial lighting would be introduced while the Chamber was still partially lit by daylight, it was nevertheless desirable that the lighting should be raised from blackout without any perceptible hesitancy in any of the panels. Special circuits and equipment could be used to provide the degree of control of the fluorescent lamps necessary at the lower end of the range, but these were considered to be an uneconomical proposition. A compromise was, therefore, made using an auxiliary lamp circuit which could be controlled easily from zero.[2]

Two tubular filament lamps are fitted in each of the 150 panels and baffled so that no direct light falls on the glazing. Each lamp is made in a special coloured glass to ensure that the appearance of the ceiling when lighted by the auxiliary lamps is similar to the effect from the fluorescent lamps.

The method of operation decided upon was for the auxiliary lamps in each panel to be controlled by a variable series resistor. When the lighting is required, the auxiliary lamps are switched on in the dim position and the bright-

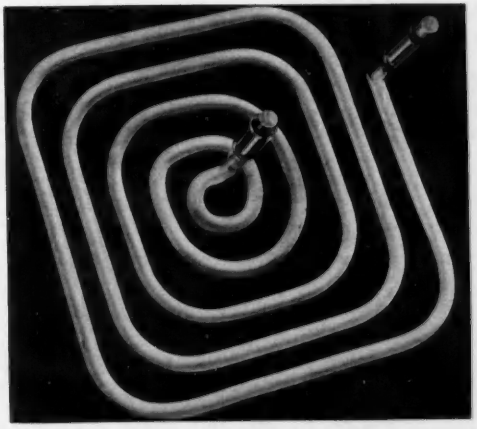


Fig. 6.—Spiral fluorescent lamp used in the cold cathode unit.

ness of the ceiling panels gradually increased as the dimmer resistor is slowly cut out of the circuit. At a predetermined position of the auxiliary dimmer, the cold cathode lamps are automatically

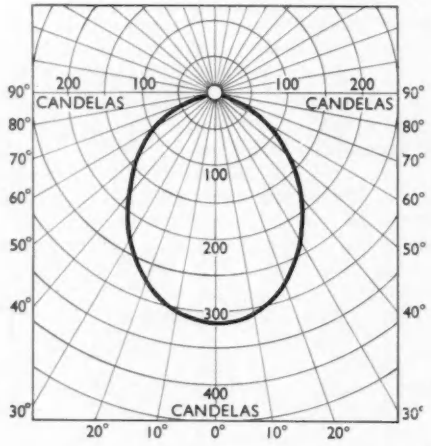


Fig. 7.—Polar curve of light distribution of a cold cathode unit; 80 per cent of the flux emitted is between the angles of 0° and 50°.

switched on in the dim position ; the intensity of the cold cathode lamps is then brought up steadily to its maximum.

At first it might be thought that the filament lamps used in the auxiliary circuit would have a short life compared with the 10,000 hours' life expected from the cold cathode lamps. The dimmer equipment, however, has been designed to cut off automatically the supply to the auxiliary circuit when the intensity of the cold cathode lamps attains about 25 per cent of its full value. This means that the auxiliary circuit will be connected for a few seconds only each time the lighting is used, and it is expected that with this arrangement the useful life of the filament lamps will be very great.

The Cold Cathode Unit.

A self-contained lighting unit in the form of a sheet metal fitting which accommodates the cold cathode lamp and its associated gear is installed behind each of the 150 panels in the ceiling. This is divided into two compartments : the lower contains the lamp and also carries a dust-tight glazing frame in order to reduce maintenance work as much as possible, while the gear is fitted in the upper part (fig. 4). One of the units with the front glass removed is shown in fig. 5.

The cold cathode lamp is 14 ft. 8 ins. long and is shaped in the form of a rectangular spiral (fig. 6) so as to light the front glass evenly. It is supported on glass insulators and the electrodes, which are at right angles to the plane in which the tube lies, return through mica dust-tight glands into the gear compartment above. A considerable improvement in the appearance of the units at wide angles of view was obtained by fitting glass mirrors to the vertical sides. These also improved the light output ratio by about 10 per cent. A polar curve of the candle power distribution in a vertical plane of one of the cold cathode units is shown in fig. 7.

Each unit is provided with a 7-core flexible cable terminating in a plug for connection to the distribution system in the roof. When the plug is withdrawn, a fitting can be removed for cleaning or servicing and temporarily replaced by one of the spare units. An electrical interlock in the form of a double-pole switch is incorporated in the cover of the upper compartment, which automatically disconnects the supply to the transformer when the cover is opened, thereby eliminating any element of danger during maintenance.

Lamp Circuit.

The high voltage required for the cold cathode lamps is obtained from double-wound transformers contained in the upper compartments of the fittings. A separate transformer is used

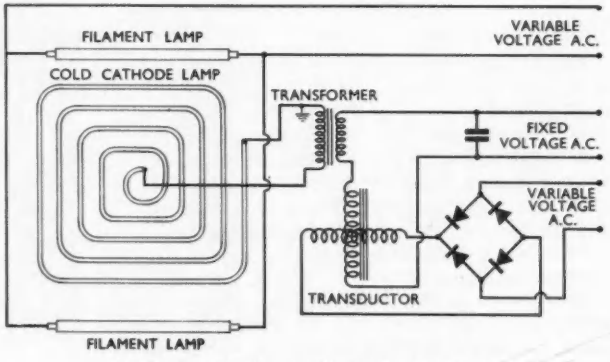


Fig. 8.—Circuit diagram of a cold cathode unit.

with each lamp and is designed to run the lamp at a maximum current of 120 mA.

Control of the lamp current, and hence the intensity, is obtained by using a transductor in the primary circuit, direct current supply for this being provided by a small metal rectifier also in the fitting.[3] The lamp is fully dimmed when no direct current is applied to the control winding of the transductor. Provision is made in the dimmer panel for varying the D.C. by adjusting the input to the rectifier. When the D.C. voltage is increased, the core of the transductor becomes partly saturated, resulting in a reduction in the effective impedance in the circuit and a corresponding increase in the brightness of the lamp.

The general arrangement of circuits is shown in fig. 8; the capacitor indicated in this diagram is for power factor correction.

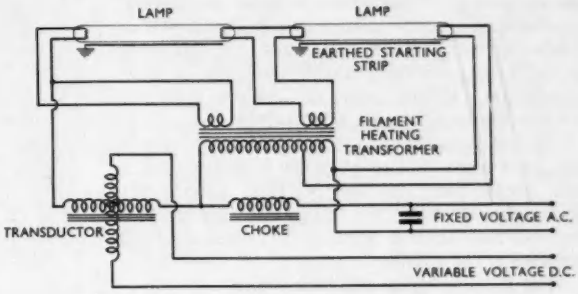


Fig. 10.—Circuit diagram of under-gallery lighting.

Under-Gallery Lighting.

It will be seen by reference to fig. 9, that the back row of benches on the floor of the House is partially screened by the gallery from direct light from the ceiling. Although sufficient light is available for reading, the faces of members using these benches might not be seen clearly by the Speaker unless additional lighting were used. A special recess was, therefore, left in the underside of the front of the gallery to accommodate a line of fluorescent lamps along all four sides of the Chamber (fig. 11).

The line of light is broken at intervals by beams on the underside of the gallery which run at right angles to the lamps. With a few exceptions, the space between the beams was sufficient to allow two 20 watt 2 ft. hot cathode fluorescent lamps to be fixed in line; these are recessed into the gallery and covered from view by obscured "Perspex." A total of 72 fluorescent lamps, four of these being 15 watt, 18 ins., is installed under the gallery and all are dimmer controlled.

The same lighting channel has been also utilised for a system of secondary lighting which can be connected to an independent D.C. supply obtained from storage batteries. A 15 watt filament lamp is fitted between each pair of fluorescent lamps for this purpose, and concealed by a similar "Perspex" screen. The "Perspex" under the gallery is coloured to match the oak and is consequently inconspicuous when the lamps are switched off.

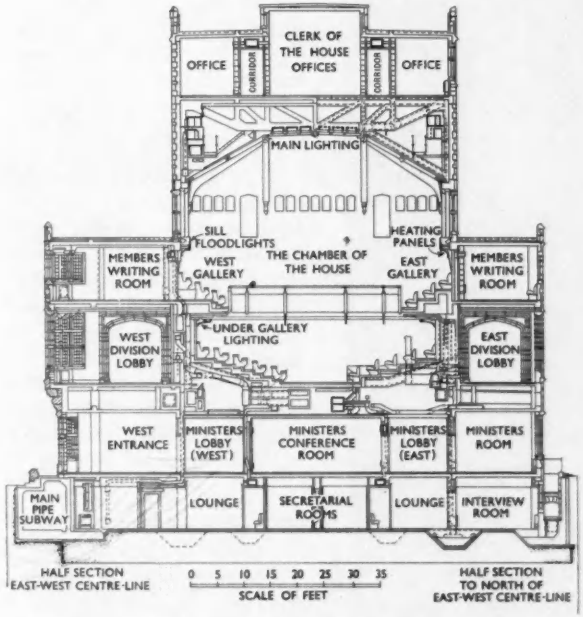


Fig. 9.—Cross-section through the House showing lighting arrangements.

Circuit Arrangements.

One set of control gear consisting of transformer, choke, transductor and power factor correction capacitor, is installed for each pair of lamps, and housed in gear boxes recessed in the floor of the gallery.

As the lamps had to be dimmed, it was necessary to use a system of control which maintained the available starting voltage and filament heating approximately constant over the complete range from dim to full brightness.[4] The arrangement shown in fig. 10 has been designed to provide adequate filament heating irrespective of the lamp current. When the lamps are operating at full brightness the electrodes are heated principally by the discharge, and, when dimmed, by the filament heating transformer.

The transductor used to vary the lamp current has been connected between the transformer and the lamps, since in this position it does not materially affect the maximum available starting voltage and reliable starting is obtained at all settings of the dimmer.

The D.C. supply required for saturation of the transductor is obtained from a rectifier and controlled by a variable potentiometer in the main dimmer panel.

Fig. 11.—Under-gallery lighting.

Sill Lighting.

Although the two systems of lighting already described constitute the main sources of illumination, a third system has been introduced so that the character and architecture of the Chamber may be better appreciated at night. This has been ingeniously concealed in the window sills along the east and west sides of the building (fig. 9). It serves two functions : (1) lighting parts of the roof and ceiling which would otherwise be dark, and (2) decreasing the contrast between the brightness of the glazed panels and of the sloping portion of the roof.

Five lighting units are installed along each side of the Chamber, each being fitted with two 8 ft. 125 watt dimmer controlled hot cathode lamps. The light is directed on to the half of the roof which is on the same side of the building as the units by means of specially designed reflectors. Since it is possible to look down on to the window sills from the highest part of the end galleries, louvres have been fitted over the units to conceal the lamps from these positions. The reflectors and louvres were also designed to prevent unwanted light falling on the sides of the windows and the open carved woodwork which runs along the front of the sills (fig. 12). Glass dust covers are provided on each unit.

Sill Lighting Circuit.

A double-wound stray field transformer is used with each lamp to step up the supply voltage and to heat the filaments. The lamp current is varied for dimming by means of a transductor inserted between the transformer and the lamp.[4] One potentiometer in the dimmer panel controls the D.C. saturation of the 20 transductors installed for the sill lighting.

Speaker's Chair.

Although considered last from the lighting point of view, the focal point in the Chamber is the Speaker's chair.

A large canopy (fig. 1) which

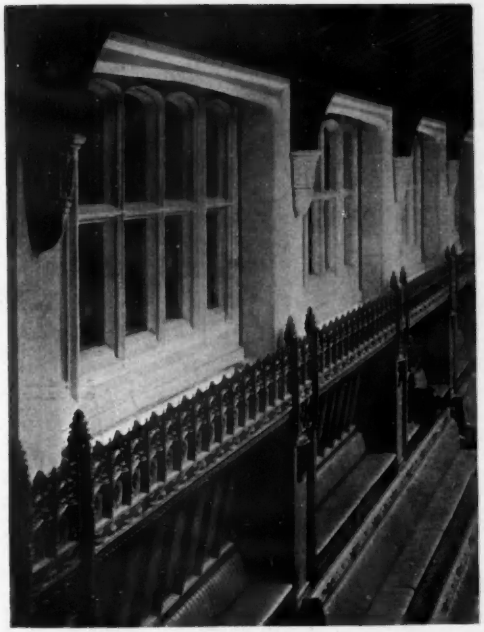


Fig. 12 (*above*).—View of cresting which conceals the sill lighting units.

Fig. 13 (*below*).—The Chamber at night as seen from the Speaker's Special Gallery.

projects from the back of the chair obstructs direct light from the ceiling and an independent light source had to be provided. One 2 ft. 20 watt fluorescent lamp has been concealed in the top of the canopy and is switched on and off by a motor-operated dimmer. A switch is fitted in one of the arm rests to enable the Speaker to have personal control of his lamp.

Illumination Data.

The average values of illumination which will be obtained in the Chamber over the 10,000 hours of life of the cold cathode lamps is shown in figs. 14 and 15. These vary between 12 and 9 lumens per sq. ft. over most of the floor. Lower levels of illumination are obtained under the gallery, but it is generally considered that adequate light is provided here. No harsh shadows are perceptible when all the lighting is on and the gradation of brightness on walls and ceiling is pleasing and effective without being abrupt.

"Intermediate" colour cold cathode lamps

TABLE 2.

NUMBER OF LAMPS, TOTAL CONSUMPTION, AND AREA LIGHTED IN THE CHAMBER.

No. of cold cathode lamps ...	150
Consumption including gear losses approx.	24 kW
No. of fluorescent lamps under gallery	72
Consumption including gear losses	2.5 kW
No. of lamps in window sills ...	20
Consumption including gear losses	3.2 kW
Area of Chamber at floor level ...	3,060 sq. ft.
Area of Chamber at gallery level	4,944 sq. ft.
Height of ceiling above floor ...	48 ft.

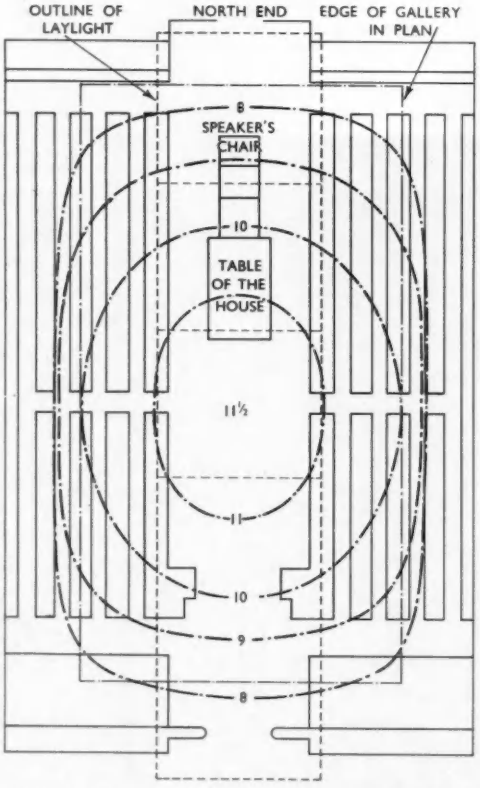
have been used above the laylight and " Mellow " under the gallery, giving the impression that the Chamber is flooded by sunlight without misrepresenting the colour of the timber. A combination of " Mellow " and " Natural " lamps is used in the sills. A general impression of the gradation of light distribution can be gained from fig. 16. Technical data concerning the installation in the Chamber are given in Table 2.

Electricity Supply System.

The lighting is distributed across two separate 415/240 volt, 3 phase, 50 cycle, 4-wire services from the main switchboard, and secondary lighting is automatically connected to a 240 volt D.C. battery system should the A.C. supplies fail. Fig. 17 shows how the circuits have been distributed. Panels 1, 3 and 5 of the laylight are connected to phases *a*, *b* and *c* respectively of supply No. 1 ; panels 2 and 4 are connected to phases *a* and *c* respectively of supply No. 2. The under-gallery is on phase *b* of supply No. 1 and sill lights are on phase *b* of supply No. 2. This arrangement of distribution ensures sufficient light in the House in the event of either supply failing. The emergency system which includes the lamps under the gallery already referred to, and additional lamps under the sills, is normally on as part of the main lighting, so that there would be no total interruption of the lights in the event of both the A.C. supplies failing.

THE CHAMBER—CONTROL OF LIGHTING.

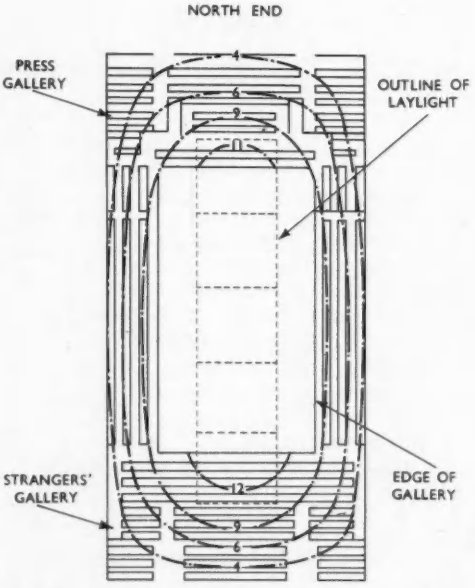
The lighting in the Chamber is switched on and off from the engineer's control room in the basement. A small control panel is fitted with push-button switches for remote control of the dimmers and is fixed alongside the engineer's desk ; these enable the engineer to increase or decrease the illumination as necessary. Indicator



ILLUMINATION IN LUMENS/SQ. FT. AVERAGE VALUES THROUGHOUT LIFE.

PLAN OF FLOOR AREA SHOWING APPROXIMATE POSITION OF BENCHES.

Fig. 14.—Isophot diagram showing illumination over the main floor area.



ILLUMINATION IN LUMENS/SQ. FT. AVERAGE VALUES THROUGHOUT LIFE.

PLAN OF GALLERY AREA SHOWING APPROXIMATE POSITION OF BENCHES

Fig. 15.—Isophot diagram of illumination at the gallery level.

Fig. 16.—The Chamber at night, showing the gradation of light distribution.

instruments are recessed into the panels to show the intensity of the main ceiling light, while coloured pilot lights show when the lamps under the gallery and in the sills are alight.

As the engineer has other services besides the lighting to control from this room, a periscope has been installed through which he can obtain a general view of the Chamber. The eyepiece is over his desk and the periscope head is some 60 ft. above in the roof of the Chamber.

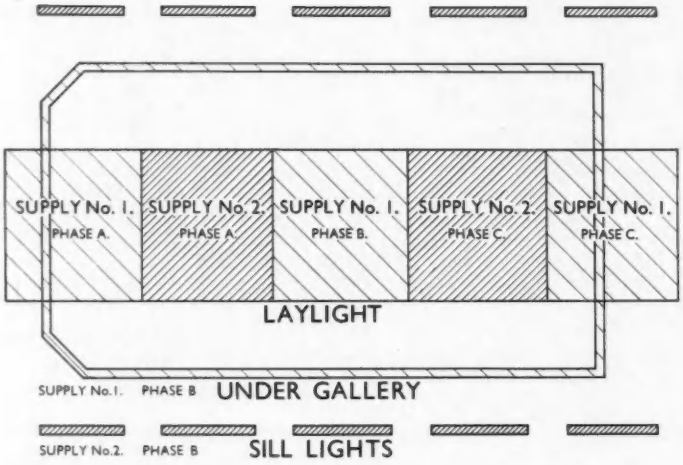


Fig. 17.—Diagram of distribution of electric supply in the Chamber.

Dimmer Panel.

The dimming equipment for the lighting in the Chamber is installed in a plant room on the same level as the ceiling and consists of four motor-driven dimmers contained in sheet steel cubicles (fig. 18).

A separate unit is provided for each of the following :

Dimmer A—Ceiling panels 1, 3 and 5.
Dimmer B—Ceiling panels 2 and 4.
Dimmer C—Under gallery.
Dimmer D—Window sills.

Three push-button switches are fitted on the front of the panel for each motor, two of these are for starting the motor in either direction, and the third stops the dimmers at any predetermined or desired position. The push-button switches and indicators are duplicates of those in the engineer's control room and are for local operation and testing.

In addition to the isolators for the incoming supplies and sub-circuits, switches are fitted to cut out the potentiometers if necessary. Hand wheels on the front of the panels are fitted with a changeover lever to disengage the motor drive and can be used to operate the dimmers manually in the event of motor failure. When operated by the motors, the dimmer speed has been arranged to bring the lights from "off" to "full-on" in one minute.

Operation of Ceiling Dimmers.

Although the two dimmer banks for the ceiling lighting are independent they are normally operated together by pressing the corresponding push buttons at the same time. When the push-button switches are closed to bring the lighting from the "off" position, the action is as follows :

The dimmer arms begin to rotate and

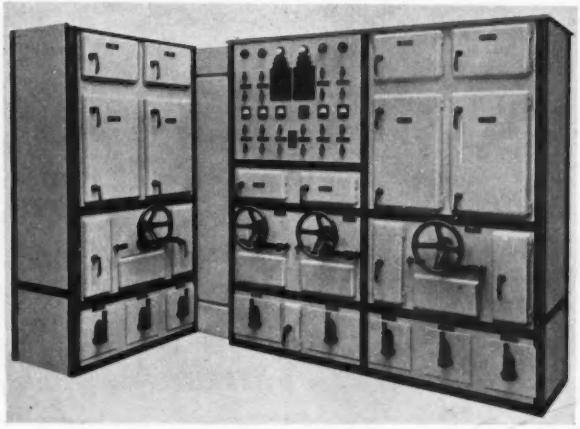


Fig. 18.—Front elevation of dimmer panel.

cause contactors to close in the auxiliary lamp circuits. As the resistance in series with the auxiliary lamps is gradually reduced, the brightness of the ceiling panels and the illumination in the Chamber increase. When the auxiliary lamps attain full brilliance, other contactors close, thereby connecting the supply to the transformers and rectifiers in the cold cathode lamp circuit. At this moment there is no excitation in the D.C. windings of the transductor, and consequently the cold cathode lamps are operating at their lowest brightness. As the contact arms of the potentiometers rotate, the brightness of the cold cathode lamps increases, and when it has reached about 25 per cent of the maximum, a trip switch automatically disconnects the auxiliary lamp circuits. Adjustable limit switches can be pre-set to stop the contact arms of the potentiometers at any predetermined part of their travel, so that the normal maximum illumination can be adjusted to suit the requirements of those using the House and also to maintain the level of illumination as the lamps age.

When the "dim" buttons are pressed, the reverse sequence takes place and the auxiliary lamp circuits are reconnected as the cold cathode lamps are dimmed.

Under-Gallery and Sill Dimmers.

The controlling elements of the under-gallery and sill lighting are two variable potentiometers which are connected to the D.C. side of metal rectifiers. One of these controls the intensity of the 72 lamps installed under the gallery and the other the 20 lamps in the sills. The contactors

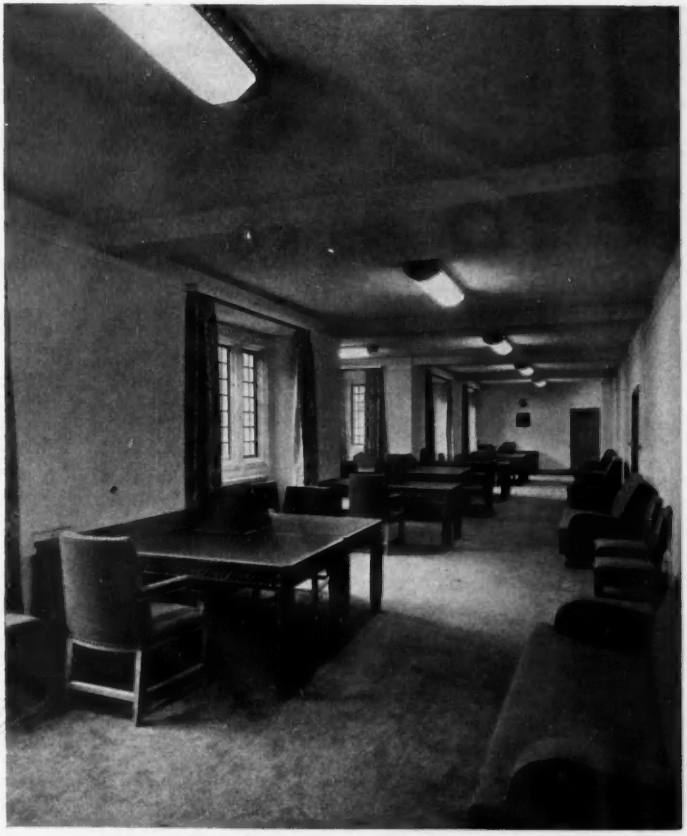


Fig. 19.—One of the members' writing rooms, equipped with bronze lighting fittings each of which contains four 40 watt fluorescent lamps.

which connect the supply to the filament heating transformers close when the " up " buttons are pressed. As the contact arms of the potentiometers rotate, the cores of the transductors are saturated and the lamp current increases. The potentiometers are also fitted with adjustable motor trip switches for automatically stopping the dimmers at different positions.

LIGHTING IN OTHER PARTS OF THE BUILDING.

The artificial lighting in other parts of the House of Commons follows conventional practice. More than 400 spaces in the new building were required to be lit, such as conference rooms, lobbies, lifts and so forth. Fluorescent lighting has been used extensively except for staircases, telephone booths and some of the plant rooms, where tungsten lamps have been employed.

COMMONS LOBBY.

An interesting part of the building which called for special lighting arrangements was the Commons Lobby. The height of the lobby at once suggests a perpendicular lighting unit to harmonise with the architectural features. Five ornamental bronze fittings have been suspended from the ceiling and besides providing adequate general illumination, they enable the beauty of the windows and sculpture work to be fully appreciated. Ten 40 watt fluorescent lamps are arranged vertically around the outside of each fitting. Raising and lowering gear is provided for these fittings which are suspended so that the lowest part is about 15 ft. above the floor.

LAMPS AND CIRCUITS.

The fluorescent lamps throughout the House of Commons with the exception of the laylight in the Chamber are of the hot cathode type. " Warm White " lamps have been used in the lobbies on the principal floor and " Mellow " lamps in most other parts of the members' accommodation. " Natural " colour lamps are installed in those plant rooms which are equipped with fluorescent lighting. Control gear to provide instant starting has been used in all fittings and stroboscopic effect is reduced by employing twin-lamp circuits in units containing two or more lamps.

Several of the lighting fittings also contain 15 watt filament lamps which are connected to the secondary supply system. These are accommodated in the end covers and are not normally apparent.

CONCLUSION.

So often, the interior lighting of new buildings appears to be given less thought than the subject deserves, and schemes, sometimes far from ideal, may have to be devised when the building is in an advanced stage of completion. The House of Commons is a particularly interesting example of what can be done by co-operation between architect, consulting engineer and lighting engineer in so far as light sources harmonise with, and form integral parts of, the architecture.

Although Gothic in style and very different from the type of architecture usually associated with modern buildings, the House of Commons incorporates the latest techniques in lighting progress.

Now that the installation is complete, it is felt that the considerable amount of development work which had to be carried out, especially in connection with the Chamber, has justified itself by the results achieved.

ACKNOWLEDGMENTS.

The lighting installation described was planned and executed as a result of close collaboration between the following, to whom the author is indebted for permission to use the material contained in this paper : Sir Giles Gilbert Scott, O.M., R.A., Architect; Dr. Oscar Faber & Partners, Consulting Engineers; Sir Charles Mole, M.V.O., Director General, Ministry of Works. The author also wishes to extend his thanks to his colleagues, especially for the assistance he has received in obtaining data on the completed installation.

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1. Report from the Select Committee on House of Commons (Rebuilding).
2. Patent Application No. 9404/49.
3. Patent No. 611,810.
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Electrical Progress and Development

Contributed by Members of the Technical Staffs of the Works and Research Laboratories.

INTRODUCTION.

IT is a matter of considerable satisfaction that, for the second year in succession, deliveries of G.E.C. equipment to overseas markets have constituted a record, both in value and in volume.

Much capital plant, including turbo-generators and compressors, is being built for Australia, South Africa, West Africa, India and Greece. It is particularly pleasing to report that, in Canada, G.E.C. rectifier equipment is now operating in the City of Edmonton, and a considerable range of induction motors is on order for British Columbia and Alberta in addition to a large number of small motors for the Hydro-Electric Power Commission of Ontario.

It is no small achievement that the London-Birmingham Television link, which went into service in December, 1949, has been operating without interruption since its inception.

The Company takes pride in having been awarded the contract for the lighting of the entire building of the new House of Commons which, in addition to the Chamber, includes Ministers' Rooms, lobbies, secretarial offices and so forth. The G.E.C. has also been entrusted with the whole of the main lighting in the auditorium of the Royal Festival Hall of the Festival of Britain, 1951.

Considerable development has taken place in adapting fluorescent lighting for use in collieries, airports, aircraft, trains and buses. New and improved fittings have been designed for street lighting.

Progress in radio communication continues to be rapid, particularly in the development and application of multi-channel links. Nyasaland and Southern Rhodesia are examples of overseas territories to which equipment of this type is being supplied.

Systems of remote supervisory control have recently been supplied to Canada. They employ "chopped" 90 c/s signalling, and indications of meter readings can be received. When required, cyclic metering can be used, the readings being indicated automatically in sequence.

Additional manufacturing capacity to deal with export orders is now available with the completion of the new Heavy Plant and Turbo Shops at Witton Works. Further extensions to the Switchgear and Transformer Works are in course of construction.

POWER EQUIPMENT.

Turbo-Generators and Compressors.

The urgent need for additional power plant has been responsible for considerable orders for large turbo-alternators, both for home and overseas use.

During the year contracts have been received from the British Electricity Authority for three 75,000 kVA, 11·8 kV, 3,000 r.p.m., hydrogen-cooled sets, designed for a steam pressure of 900 lbs. per sq. in., and a steam temperature of 900 degs. F., two of which are for a new power station to be erected at Ince, near Capenhurst in the Wirral Peninsula, for the Merseyside and North Wales Division; the third set is for a further station which will be built at Hams Hall and which will be known as Hams Hall C. In all, nine 75,000 kVA hydrogen cooled turbo-generators are now in hand.

Other orders for generating plant for home use include a second set for Huddersfield Power Station rated at 37,500 kVA, 11 kV, a 6,000 kW pass-out set for the Sheepbridge Co., Ltd., and a 5,000 kW pass-out turbo-generator for the Lackenby Works of Dorman, Long & Co., Ltd. Construction of the two 37,500 kVA sets for the Huncoat Power Station, Accrington, is nearing completion; the stators for these machines are seen in fig. 1. Two 1,250 kW mixed pressure sets (fig. 2) have now been commissioned at Kingsbury Colliery in the West Midland Division of the National Coal Board. The turbines, which run at 6,000 r.p.m., are mixed pressure machines and drive salient pole alternators at 1,500 r.p.m. through double helical reduction gear. The steam supply at the stop valve is at 175 lbs. per sq. in. and the low-pressure supply from the winder exhaust is at 16 lbs. per sq. in. absolute. The high-pressure steam is taken directly from the boilers and the proportions of high- and low-

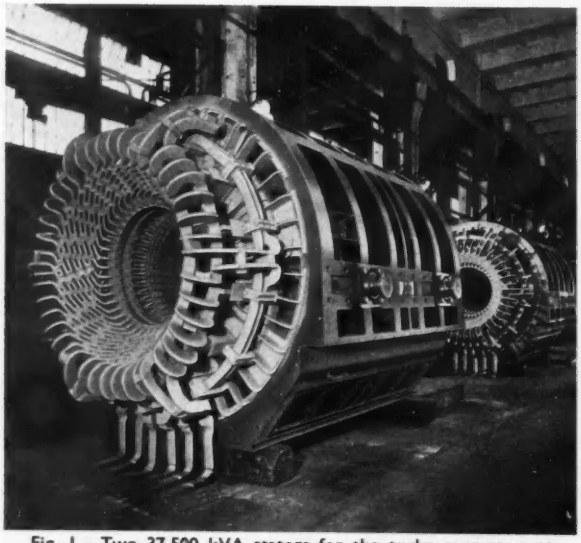


Fig. 1.—Two 37,500 kVA stators for the turbo-generators at Huncoat Power Station, Accrington.

pressure steam admitted to the turbine are controlled automatically by means of mixed pressure gear which ensures that only the minimum quantity of high-pressure steam is used to supplement the low-pressure supply at any particular loading.

In the fulfilment of export orders much generating plant has been shipped overseas, among which the largest units have been the two 47,000 kVA sets for the Orlando Power Station, Johannesburg; one of the stators in course of shipment is seen in fig. 3. Five further sets, each rated at 37,500 kVA, are on order, so that the ultimate capacity of G.E.C. plant installed in this station will amount to 422,500 kVA. Also for South Africa there are on order two 750 kW, 440 volt geared sets for the Sena Sugar Estates, a 1,500 kW back-pressure set for the Tongaat Sugar Co., Ltd. and two 2,000 kW sets for Vryheid Colliery.

Other equipment delivered to overseas customers includes a 15,600 kVA set for the Mount Isa Mines, Queensland, where three 6,250 kVA turbo-alternators are already in service; a 5,400 kVA, 6·6 kV geared set for the Athens Electric Company (fig. 4), three 1,000 kW, 415 volt geared units for Samreaboi Timber Mill, West Africa, two 1,000 kW turbo-alternators for West Bokaro Coal Mines, India, and one 1,875 kW set for the India Paper Pulp Company.

Further to previous contracts an order has

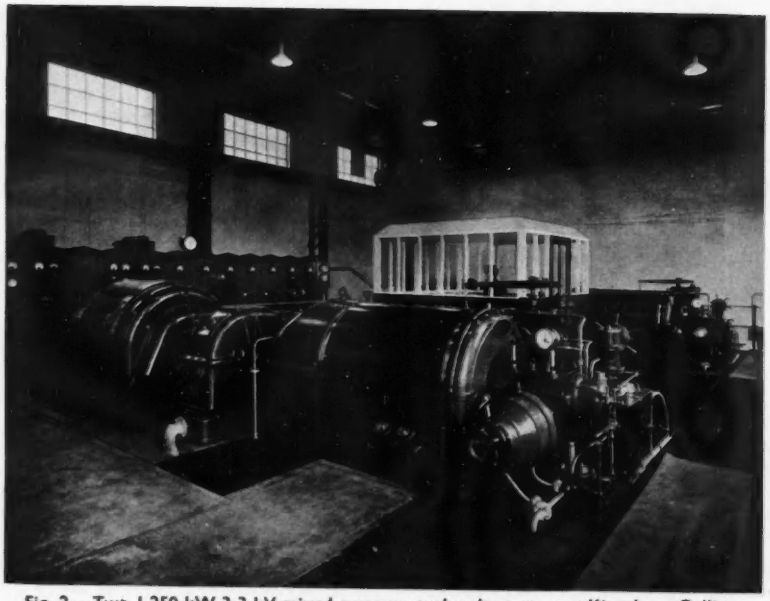


Fig. 2.—Two 1,250 kW 3·3 kV mixed pressure turbo-alternators at Kingsbury Colliery.

been received from the Anglo-American Corporation for a turbo-compressor to be electrically driven through gearing and to be capable of handling 20,000 cu. ft. of free air a minute against a pressure of 85 lbs. per sq. in.

Fig. 3.—A turbo-generator stator, weighing 82 tons, for the Orlando Power Station, Johannesburg, being loaded for shipment.

The driving motor will be a self-starting synchronous machine rated at 4,485 h.p., 1,500 r.p.m. In all, there are now seventeen turbo-compressors installed or on order for this undertaking.

For Western Reefs, South Africa, there is in hand a turbo-compressor to deliver 20,000 cu. ft. of air a minute against a pressure of 85 lbs. per sq. in. and two turbo-compressors for N'Changa and N'Kana Copper Mines to deliver 15,000 cu. ft. of air against a pressure of 90 lbs. per sq. in.

Two of the three turbo-blowers for the South African Iron and Steel Corporation have now been commissioned. Each blower has a capacity of 68,400 cu. ft. of air a minute at 20 lbs. per sq. in. and is driven at 3,000 r.p.m. by a 7,000 h.p., two-pole synchronous motor. Two compressors have also been delivered to the New Consolidated Gold Fields, Ltd., for service with the West Driefontein and Stilfontein Gold Mining Companies respectively. Each is designed for an output of 15,000 cu. ft. of air a minute at 100 lbs. per sq. in. and is driven through gearing by a 3,400 h.p. synchronous motor. A 90,000 cu. ft. turbo-blower is on order for Dorman, Long & Co., Ltd. and two 80,000 cu. ft. turbo-blowers for the Steel Company of Wales.

Hydro-electric Plant.

For the hydro-electric station at Pangani Falls, Tanganyika, additional generating capacity has now been put into commission consisting of two new sets, rated at 2,500 kW and 5,000 kW respectively, which are driven at 750 r.p.m. by Francis horizontal shaft turbines built by Boving and Co. Ltd. This brings the total capacity of the generating plant supplied up to 12,500 kW. A fifth set rated at 5,000 kW is being provided for this power station, which is illustrated in fig. 5.

Engine-driven Generators.

Shortly before the war the G.E.C. supplied a considerable amount of electrical equipment to the Bremang Gold Dredging Co., Ltd., in connection with the recovery of alluvial gold from the shallows of the Ankobra, one of the larger rivers of the Gold Coast Colony. The generating plant comprised seven 725 kW oil engine-driven alternators. Additional capacity has since become necessary and two 1,500 kW, 3·3 kV, 214 r.p.m. sets have been ordered, the first of which has already been delivered. The alternator is driven by a Crossley-Premier, sixteen cylinder,

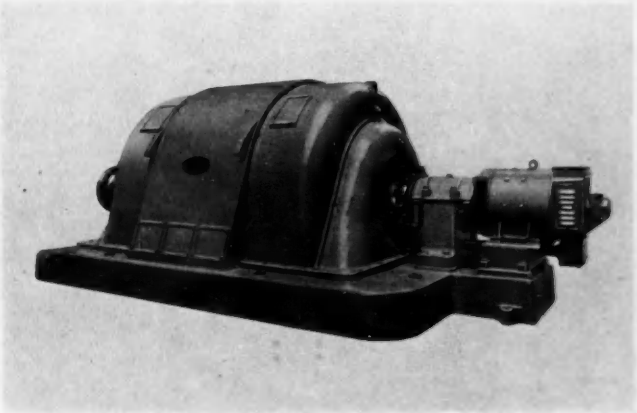


Fig. 4.—5,400 kVA geared alternator for Athens Electric Company.

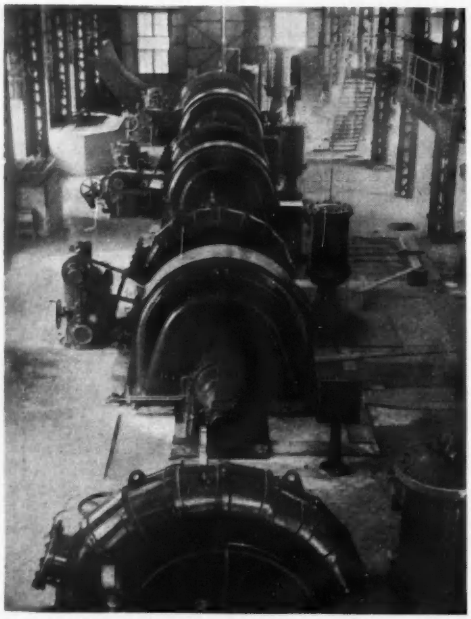


Fig. 5.—The hydro-electric station at Pangani Falls, Tanganyika.

eight crank, *vis-à-vis* horizontal engine. As can be seen from the illustration (fig. 6) the alternator is centrally disposed between two sections of the engine and this has involved a special construction to permit inspection and maintenance of the lower portion of the stator windings without partly dismantling the engine.

Normally the stator is supported by removable feet bolted on each side of the shell. Immediately below the stator is a roller cradle which is mounted in the bottom of the pit. An adjusting screw is provided by means of which the rollers can be moved into position for supporting the shell. Fig. 7 shows one half of the stator during erection with the roller cradle in position. It will be seen that when the feet are removed the stator is completely supported by the rollers. Holes are provided in the shell to enable the stator to be barred round by the crane.

Among other overseas orders for engine-driven generators, mention may be made of 14 diesel-driven sets, totalling 1,750 kW, for the Province of Bombay.

Transformers, Chokes and Capacitors.

As in former years many orders have been received for large transformers from the British Electricity Authority and from the countries of the Commonwealth. Seven 45,000 kVA, 132/33 kV units are in hand for the B.E.A. and two 15,000 kVA, 33/11 kV units for the Eastern Electricity Board. Four large transformers, each of 45,000 kVA capacity, have been delivered, during the period under review, to various sub-stations of the B.E.A. in addition to two 41,000 kVA generator transformers for the Huncoat Power Station, Accrington, as well as a number of smaller units. The first of the six 70,000 kVA generator transformers for Uskmouth Power Station is now approaching completion.

It will be appreciated that the transport of a unit of this size involves a number of problems. It is impossible to deliver it directly to site by road owing to restrictions imposed by the permissible loads on the various bridges over which it would have to pass. An alternative route by road to Liverpool, sea to Cardiff and road to

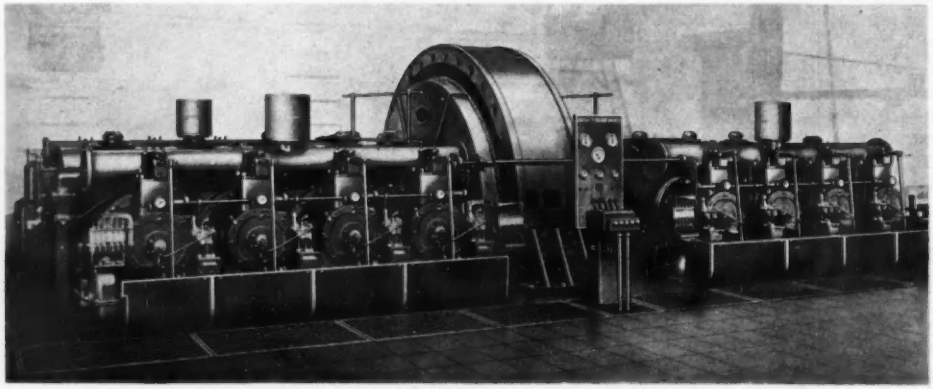


Fig. 6.—1,500 kW engine-driven alternator in the power house of the Bremang Gold Dredging Co., Ltd. in the Gold Coast Colony.

Newport was rejected on the grounds of cost, and it was finally decided to dispatch direct by rail. A special concession was obtained from the railway authorities whereby the 120 ton crocodile truck could be used for the 130 ton load.

Overseas orders include six 7,500 kVA, 132/33 kV transformers for the Machkund Hydro-Electric Scheme, India, and thirteen transformers, ranging from 1,000 to 4,000 kVA and aggregating 30,000 kVA, for the Nangal power project. These units will be installed at five 66 kV and three 33 kV outdoor substations.

A 1,500 kW rectifier transformer for the New South Wales Government Railways is seen in fig. 8 ; it embodies current transformers for use with the arc suppression equipment referred to in the section on mercury arc rectifiers. It may be added that many orders are in hand for rectifier transformers for home and overseas installations.

A contract has been received from the Air Ministry for small transformers for taxi track lighting. Special features of the design include hermetic sealing of cover and glands, high-operating efficiency and high leakage reactance to withstand prolonged short circuit of the output terminals without damage to the transformer. The units will be suitable for service under all conditions of climate and are normally installed in unventilated concrete pits which are liable to severe flooding.

Much progress has been made in the production of Class B insulated transformers for the Admiralty for use aboard ship. Orders in hand cover several hundred units varying in size from 0·5 kVA to 28 kVA (fig. 9). These transformers are specially designed to withstand the severe mechanical shock tests and electrical short circuit tests specified by the Admiralty. Considerable development work has been necessary to enable the equipment to meet all requirements. One of the features of the general construction is ease of removal of the cases to allow ready access to terminals and windings.

During the year a number of standard catalogue type transformers has been re-designed so as to take advantage of improved materials and winding technique with the object of securing better performance at lower cost.

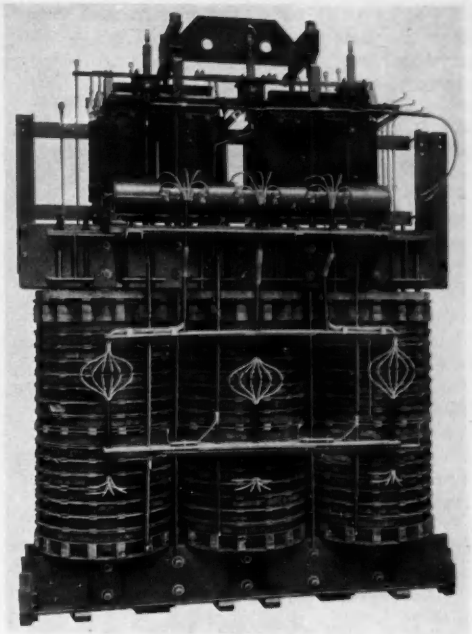


Fig. 8.—1,500 kW, 33 kV rectifier transformer for the New South Wales Government Railways with current transformers for arc suppression equipment.

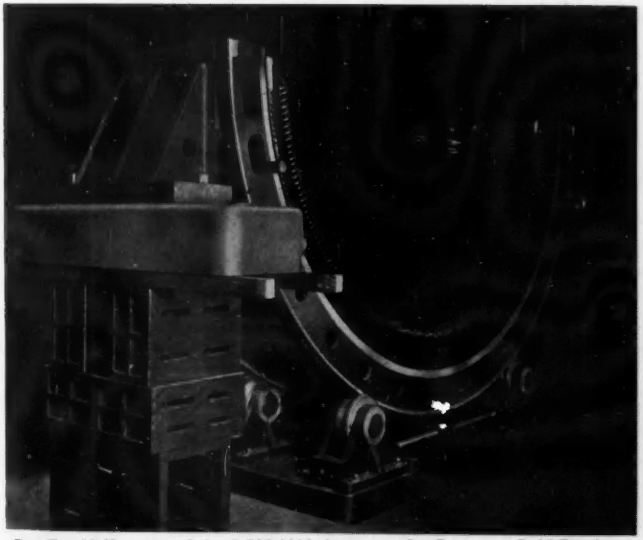


Fig. 7.—Half-stator of the 1,500 kW alternator for Bremang Gold Dredging Co., Ltd., showing the roller cradle in position.

The range of power factor correction capacitors has now been extended to include units suitable for operation in ambient air temperatures up to 50 degs. C. (122 degs. F.).

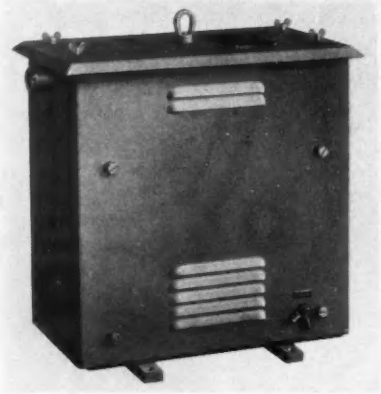


Fig. 9.—15 kVA, 440/117 volt, 60 cycle transformer with Class " B " insulation for the Admiralty.

A new range of chokes, known as " brick " chokes, has been introduced for use with the 80 watt fluorescent lamp, and these are now in large-scale production. The new design makes possible a lower-priced article with a better performance, and the chokes are lighter than earlier models. Besides increased efficiency, special attention has been paid to silent operation and the new chokes are most suitable for use in very quiet situations. Exhaustive tests have proved that the choke is free from leakage of compound under all service conditions.

A range of combined choke and starting transformer units has also been developed for the 80 watt lamp with the object of eliminating the starting switch. The choke and starting transformer are mounted together in a single compound filled container and, as in the case of the " brick " choke, particular attention has been given to quiet operation and freedom from compound leakage.

During the year there has been a demand for transformers to operate cold cathode fluorescent lamps in exceptionally quiet surroundings, where the transformers could not be mounted remote from the lamps, and special designs have been evolved which are successful in reducing the noise to a very low level. It is noteworthy that transformers of this type have been installed in the Elstree film studios and the lecture theatre of the Institution of Electrical Engineers.

The existing range of chokes for operating high-pressure mercury vapour lamps for street lighting has also been re-designed and the new 400 watt and 250 watt units are now in production.

Transformer Tapping Switches.

Two new types of on-load tapping switches, N and B, have been added to the existing range. The type N switch has been produced for use with 33 kV transformers ranging from 10,000 kVA to 20,000 kVA. It is rated at 400 amps, and provides 15 ratios. The selectors are of similar type to those used for the type J switch the design of which has been proved over several years of service and has been described and illustrated in an earlier issue of this Journal.[1] The diverters are of the contactor type. Tapping switches of this design are now being supplied for two 15,000 kVA transformers for the B.E.A.

For transformers up to 750 kVA capacity at 11 kV and correspondingly reduced outputs at 6·6 kV and 3·3 kV, the type B switch has been developed (fig. 10). It is rated at 25 amps.

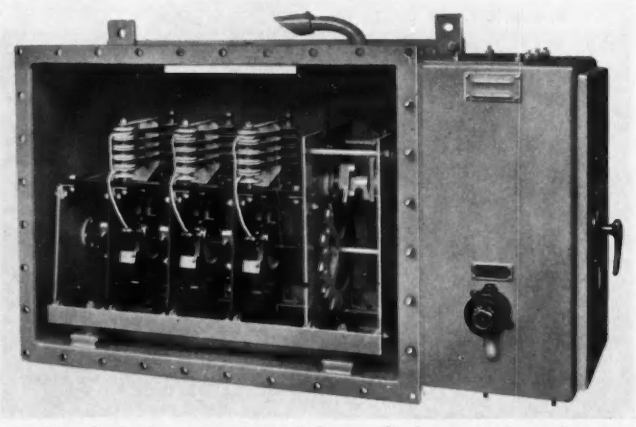


Fig. 10.—On-load tap changing switch, type B, showing resistor elements and face plate tap changing switches.

and provides 11 ratios. Unlike the heavier duty on-load switches this design makes use of resistor elements in place of a tap switch choke,

[1] " Electrical Progress and Development," *G.E.C. Journal*, Vol. XIV, No. 3, February, 1947, pp. 126-7.

Fig. 11.—22 kV metalclad switchboard at Port Elizabeth, Cape Province. The breakers are of the spring closing type.

tap changing being effected through face plate pattern switches.

METALCLAD SWITCHGEAR.

Several important contracts for 33 kV heavy metalclad switchgear have been completed during the year ; they include thirteen units for the Midland Electricity Board and nine for the Clydes Mill power station of the B.E.A., all rated 750 MVA at 33 kV ; the last-mentioned contract includes also ten units rated 1,500 MVA at 33 kV. The sixteen 1,000 MVA units for the White Bay power station of the New South Wales Government Railways have also been shipped. Fig. 11 shows a 22 kV metalclad switchboard which is in service at Port Elizabeth, Cape Province, in connection with the development of a new industrial area known as the Neave Township.

Many units in the smaller range of metalclad switchgear, rated from 250 to 350 MVA, have been completed during the year, including thirty-seven 6·6 kV units for the City of Glasgow Transport, Tramway Section. Orders recently received include one for an eighteen panel board for the Pyrmont "B" power station, Sydney.

AIRBREAK SWITCHGEAR.

Reference has been made in earlier volumes of this Journal[1] to the range of airbreak switchgear for voltages from 400 to 3,300 volts. This type of equipment continues to find increasing application, particularly in connection with the control of power station auxiliaries, as is evident

[1] "Electrical Progress and Development," *G.E.C. Journal*, Vol. XVI, No. 1, January, 1949, and Vol. XVII, No. 1, January, 1950.

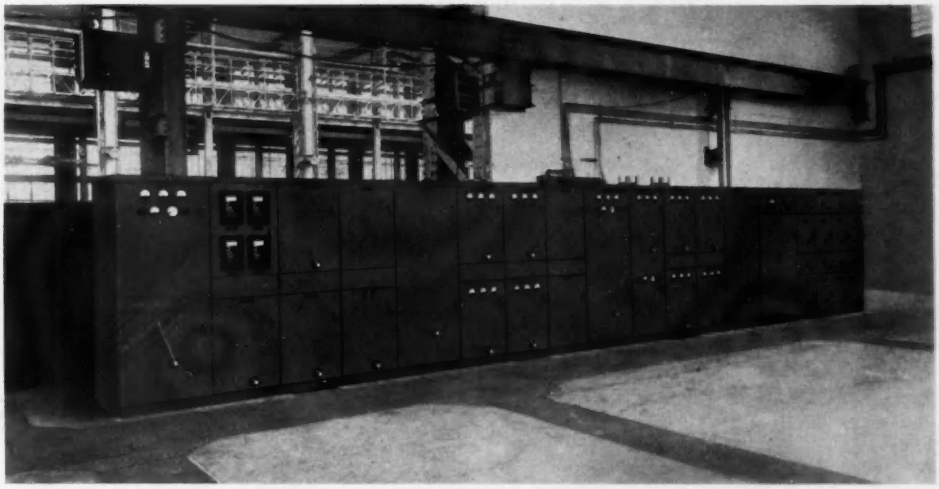


Fig. 12.—440 volt airbreak switchboard in an industrial substation in Birmingham.

from orders received, one of which covers twenty 400 volt units for controlling motor circuits in the Woolwich power station. A typical switchboard of this design is seen in fig. 12 which gives an excellent idea of the neat and pleasing appearance.

Outdoor Equipment.

A new design of outdoor breaker with a capacity of 2,500 MVA at 132 kV has been completed and a prototype is in course of construction. In undertaking this development careful consideration was given to the question of so designing the new components that they can be used in converting the many G.E.C. breakers in service on the British Grid to an increased breaking capacity of 2,500 MVA. Many of these breakers have already been modified to the new design and tests have shown that their performance is outstanding ; the total break time from the receipt of the trip impulse to the clearance of the fault being under 0·07 seconds at all breaking currents. The interior of a breaker which has been converted to the greater breaking capacity is seen in fig. 13 which also shows the disposition of the moving contacts, arc control pots and switching resistances.

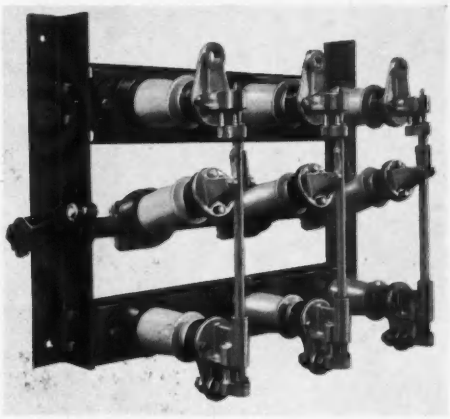


Fig. 14.—11 kV, 400/600 amp. triple pole sliding contact indoor type isolator for the North Gujarat grid scheme.

Of the numerous contracts for 66 kV and 33 kV circuit breakers, many have come from overseas. From Australia alone the orders

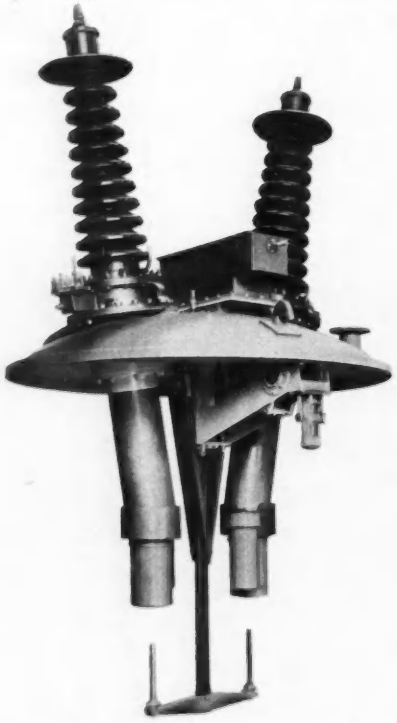


Fig. 13.—Interior of one phase of a 3-phase, 132 kV, 2,500 MVA outdoor oil circuit breaker.

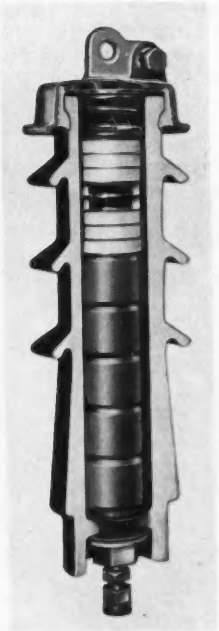


Fig. 15.—Section of a surge diverter, type MGP-R, rated at 12·5 kV.

received cover twenty-nine 33 kV breakers for Brisbane, Sydney and Warringah Shire Council, New South Wales. A further three 33 kV breakers are being supplied in connection with the North Gujarat electric grid extension in India, and seven 66 kV and three 33 kV breakers for service on the East Punjab Nangal power project.

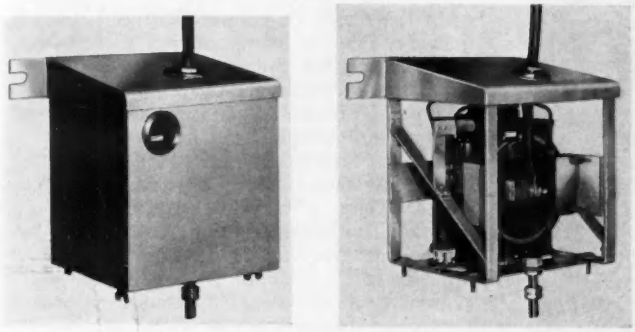


Fig. 16.—Exterior and interior views of the new surge counter.

Several important contracts have been received for equipment for switching stations overseas. Much of the gear for the ten substations on the North Gujarat grid scheme is now on site. A new design of indoor triple pole isolator (fig. 14) has been developed in connection with this scheme which is of the sliding contact type, arranged for gang operation, and is suitable for service in substation kiosks where space is limited. A new contract recently placed for extensions to this scheme covers equipment for six further substations and includes 66 kV and 33 kV outdoor isolators and 11 kV kiosks, in addition to the three 33 kV outdoor oil circuit breakers already mentioned.

For the East Punjab Nangal power project, besides the transformers and outdoor oil circuit breakers, the complete equipment for eight outdoor switching stations is being supplied. The contract covers transformers, oil circuit breakers, 66 kV isolators, eight 11 kV truck boards amounting in all to 67 panels, control and relay boards and cabling.

At home a large amount of work is in hand in connection with extensions to the Grid besides the provision of equipment for the new 132 kV outdoor substations at Smethwick and Oldbury.

Surge Diverters.

A new range of surge diverters (fig. 15) has been developed for rural distribution systems. These diverters have been designed for service under all conditions of climate on systems from 2·2 kV to 33 kV normal voltage ; they consist of spark gaps and non-linear resistors, housed in green glazed high tension porcelain containers which are hermetically sealed against the entry of moisture. The larger units are suitable for bracket mounting only; but smaller sizes can be supplied for either bracket mounting or for suspension from the overhead line.

Surge Counters.

For use with surge diverters, the surge counter (fig. 16) automatically records the

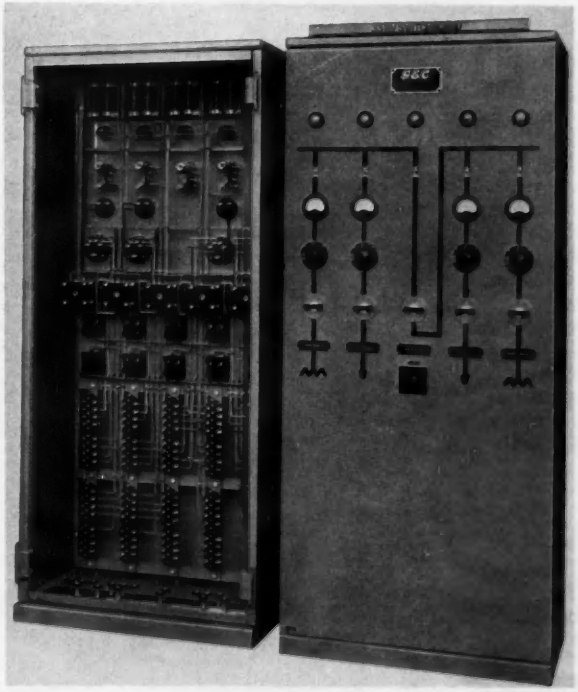


Fig. 17.—Rear and front views of a 33 kV control panel of the new cubicle construction.

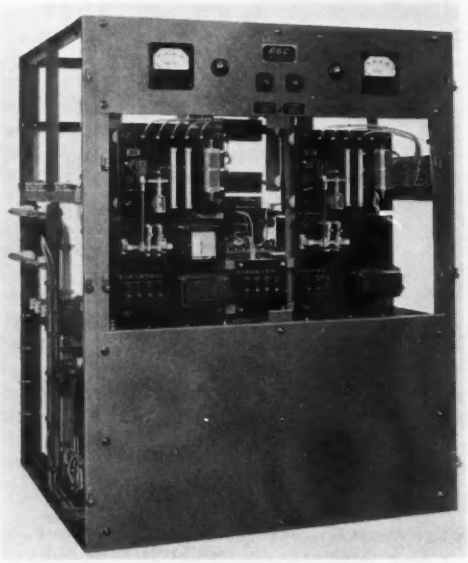


Fig. 18.—Control cubicle for the 1,500 kW, 1,500 volt rectifier for the Sefton substation of the New South Wales Railways, in which is housed the electronic equipment for arc suppression.

number of transient over-voltages appearing in overhead lines and associated equipment. The apparatus is housed in a weatherproof sheet steel case provided with a glass window through which the readings of the recorder are visible. The equipment comprises a large diameter, low resistance, non-linear resistor shunted by an oil-filled paper capacitor, and the operating coil for a cyclometer type counter. The counter can deal with a very high surge current, and the condenser has a surge strength well in excess of the maximum voltage developed across the resistor when the associated diverter is discharging current up to 50,000 amps. Provision is made for testing the counter mechanism by means of an auxiliary supply, a 60 volt dry battery being suitable for this purpose.

Control Boards.

The new unit design of sheet steel cubicles for control boards, high- and low-voltage switchboards, contactor panels and the like was described in an earlier issue of this Journal.[1] Several boards of this type have been supplied to the B.E.A. and for overseas service ; a typical panel is shown in fig. 17. In addition, two large boards constructed on this principle are now in hand for the Clydes Mill and Nechells power stations, each of which will have a total length of some 150 feet.

[1] "Electrical Progress and Development," *G.E.C. Journal*, Vol. XVII, No. 1, January, 1950.

Mercury Arc Rectifiers.

In the review of progress in this Journal in January, 1950, a description was given of new types of rectifier cylinders developed to meet special requirements, and the putting into service of 1,500 volt traction equipments. The past year has seen a number of further equipments of this type, an interesting innovation being the 1,500 kW twin-cylinder equipment for New South Wales with which control grids are employed for arc suppression. A feature of this is the incorporation of electronic means for applying the arc suppression (fig. 18) which represents a considerable advance on earlier electro-mechanical methods.

It is of particular interest to record briefly some of the many other rectifier installations supplied to, or on order for, overseas customers.

In the field of 1,500 volt traction, a repeat order has been placed by the Netherlands Railways for two mobile substations similar to those which went into service in the spring of 1949. For the New Zealand Government Railways eight 1,500 kW, 1,600 volt units are now in course of delivery, the first of which is illustrated in fig. 19.

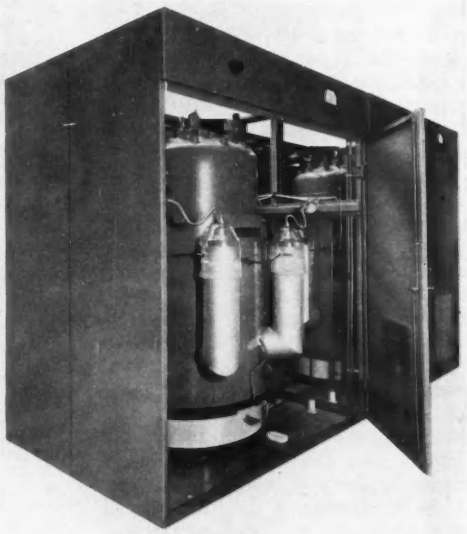


Fig. 19.—One of eight 1,500 kW, 1,600 volt, twin cylinder rectifier equipments for the New Zealand Government Railways.

Also during the year the first British steel tank pumpless rectifiers went into service in Belgium on the Chemins de Fer Vicinaux, where three 630 kW units are now in commission. Another notable event was the entry into service of the 1,760 kW, 575 volt triple cylinder equipment supplied to the City of Edmonton, Canada. Further rectifier plant delivered to the Commonwealth includes four 600 kW installations for Melbourne Tramways and a repeat order for a 500 kW grid controlled equipment for New Delhi to run in parallel with the existing plant, the grid control being arranged to operate both units together.

Other rectifiers, which are required for electrolytic purposes, include a 660 kW, 440 volt plant supplied to Klipfontein Organic Products, South Africa, and three 870 kW, 200/250 volt units for the I.C.I. at Yarraville, Australia.

For home use, the Company has supplied a number of rectifiers for uninterrupted operation over very long periods among which may be mentioned four 625 amp., 500 volt equipments (fig. 20) for a chemical works in the north-west of England, from whom an order for a further six units has now been received. A feature which this installation has in common with that for the New Zealand Government Railways, seen in fig. 19, is the mounting of the cylinders on the floor of the substation with the cooling fans below. In the electrolytic example they are separately mounted. Other important home installations include three 1,500 kW, 600 volt

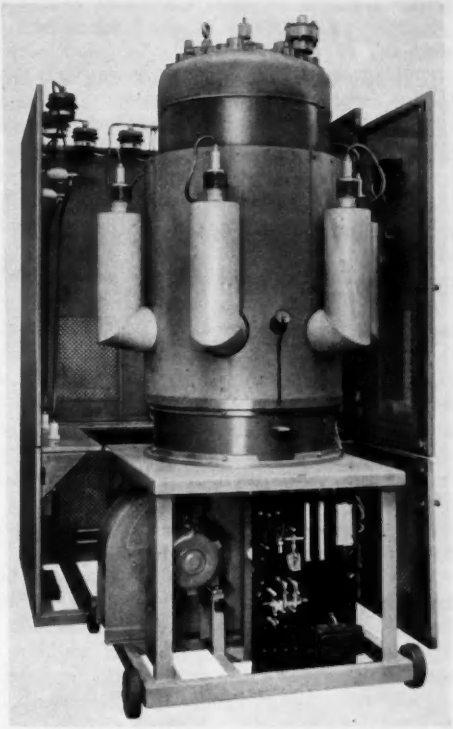


Fig. 21.—1,500 kW, 1,500 volt truck type rectifier cubicle.

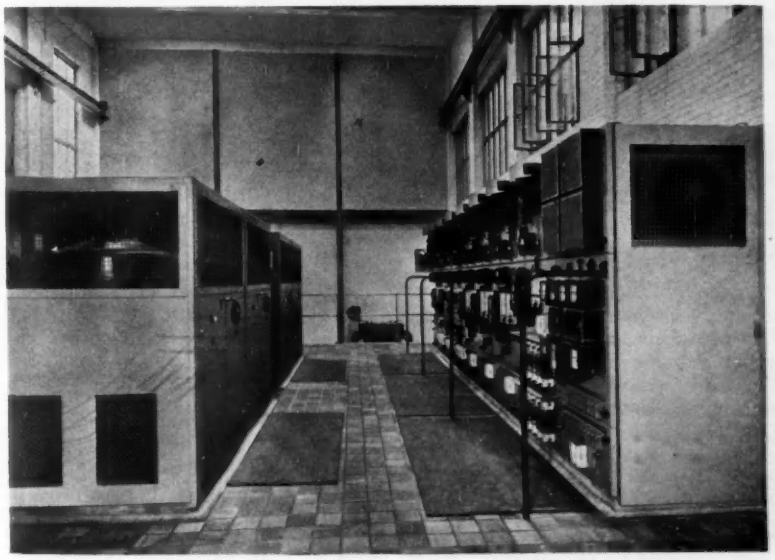


Fig. 20.—Two of four 625 amp., 500 volt twin cylinder rectifier equipments for service at a chemical works. The D.C. control board is seen on the right.

rectifier units for Glasgow Corporation and six 1,600 kW, 440 volt units for the Steel Company of Wales.

In the matter of new design the emphasis this year has been on improved appearance and arrangement of the cubicles in which the rectifiers are housed. The major developments have been, first, the change to modern methods of brake-press construction which has undoubtedly enhanced the general appearance of the cubicles and, second, the introduction of a withdrawable truck type of mounting for the larger units, (fig. 21). The advantages of this latter arrangement, in which the rectifier auxiliaries are mounted in the lower part of the truck, are ease of installation, without the use of overhead lifting gear, and greater accessibility for inspection, cleaning and maintenance. It should be added that the dimensions and weight of the smaller units have been considerably reduced so that the equipment inside the cubicles is within easy reach and, therefore, the fixed mounting of these rectifiers has been retained.

New contracts placed with the Company in the course of the year include two 2,000 kW, 3-wire equipments for Tullis Russell & Co., Ltd. with static balancing by the use of additional rectifier cylinders ; and a repeat order for three 625 kW equipments from Whitehall Securities for Athens Tramways. It is worth recalling that the original substations were equipped in 1938 and that these rectifiers suffered the vicissitudes of enemy occupation but were still in service at the end of the war.

Mention has already been made of plant supplied to the Steel Company of Wales ; present orders in hand for the steel industry include three 500 kW rectifiers for Stewarts and Lloyds, Ltd. and a number of 230 volt units, totalling 5,000 kW, for Hadfields, Ltd. For Delhi Central, an order for six 500 kW, 500 volt rectifiers is in course of execution.

Protective Gear and Relays.

In an earlier issue of this Journal[1] a full description was given of load bias busbar protection. Several comprehensive schemes embodying this system of protection are now in service, including those at the Clydes Mill power station, Glasgow, the 33 kV substation at Castleton, Lancs., and in four 33 kV substations on the Liverpool Street to Shenfield line of the Eastern Region, British Railways.

[1] "The Protection of Busbars and Switchgear," by J. A. Fitzpatrick, *G.E.C. Journal*, Vol. XVII., No. 3. July, 1950.

Biased Differential Two-Pilot Feeder Protection.

During the past year a biased differential two-pilot feeder protection scheme has been developed for use on distribution networks where only low ratio or existing low output current transformers are available for operating the relays.

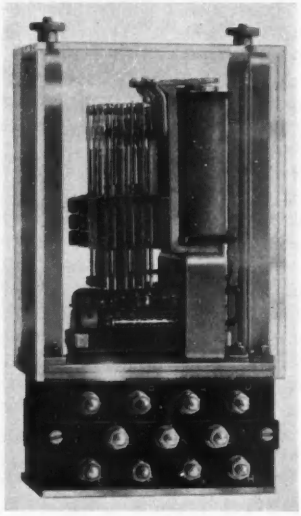


Fig. 22.—Plug-in type telephone relay unit.

It is also applicable to " Teed " feeders. The scheme, which comprises a summation transformer and a single-pole biased differential relay located at each end of the feeder, makes use of the well-known principle of the four-pilot or three-pilot schemes. Under normal conditions, equal currents flow through the restraining and operating coils of the relays, but if an internal fault occurs the balance is upset and the relay operates.

Tests carried out on one installation using this form of protection with low output current transformers of 300/5 ratio, which were previously used for instruments, gave the following performance figures :

Earth faults :
- (red phase) 33 per cent of C.T. rating.
- (yellow phase) 36·6 per cent of C.T. rating.
- (blue phase) 54·5 per cent of C.T. rating.

Phase faults :
- (red to yellow) 133 per cent of C.T. rating.
- (red to blue) 67 per cent of C.T. rating.
- (blue to yellow) 123 per cent of C.T. rating.
- (3 phase symmetrical) 95 per cent of C.T. rating.

The scheme was completely stable for all types of through-fault currents up to 800 amps.

Generator Protection.

Improvements in the design of the relay for the biased differential protection of generators have resulted in more rapid operation, and it is now possible to provide relays with operating times of 50 milliseconds (2½ cycles on a 50 cycle supply) without detracting from their performance with respect to fault setting or the stability of the scheme. This system of protection is being used extensively for generating stations of the British Electricity Authority.

Relays.

For ring main or parallel feeder protective schemes, a directional over-current or earth fault relay, type Bd, has been developed. This relay which is complementary to the non-directional relay, type B, is designed to give the time/current characteristic as recommended in British Standard No. 142 (1942), the setting ranges of standard relays being 50 per cent to 200 per cent for over-current protection and 10 per cent to 40 per cent or 20 per cent to 80 per cent for earth fault protection.

Other relays which are now available utilising the same movement as the type B over-current relay include reverse power, overpower and underpower units.

Automatic Power Factor Correction Relays.

For the purpose of providing automatic power factor correction, a reactive kVA measuring relay has been designed. It operates in conjunction with a 10-step sequence relay which initiates the switching in or out of capacitors to effect the necessary correction to the power factor. Provision is made for adjusting the setting of the reactive kVA relay, which with its associated current transformer can be used in any automatic power factor correction scheme.

Plug-in Type Telephone Relay Units.

These units, illustrated in fig. 22, have been produced primarily for service in alarm schemes in main power station control rooms, although they are equally suitable for many other indicating schemes such as may be required on remote control and supervisory equipments. A removable "Perspex" cover is fitted to the unit which may house one, two or three telephone relays. The apparatus is suitable for voltages up to 250 D.C., the electrical circuits being designed to withstand a test pressure of 2 kV to the frame for one minute.

MINING GEAR.

Orders have been received from the National Coal Board for two geared A.C. skip winders and associated control gear for Manvers Main Shafts, Nos. 1 and 2. The motors are rated at 1,500 h.p. and 2,250 h.p. respectively, the winders being of the bi-cylindro-conical drum type. For No. 1 Shaft the equipment is designed to raise 6 tons of coal per wind from a depth of 1,143 feet ; that for No. 2 shaft will raise 8 tons per wind from a depth of 2,118 feet. The new horizontal type liquid controller will be installed for both equipments.

For the South Western Division of the National Coal Board an order has been received for the mechanical equipment of winders in connection with the Maerdy reorganisation scheme. The down cast winder will have a bi-cylindro-conical drum 13-20 ft. and is designed to raise 6 tons from a depth of 1,224 ft. The upcast shaft is to be fitted with a double drum winder, one loose and one fixed, both 14 ft. in diameter. This winder will be required to deal mainly with the stone load and the raising and lowering of men, in addition to other miscellaneous duties.

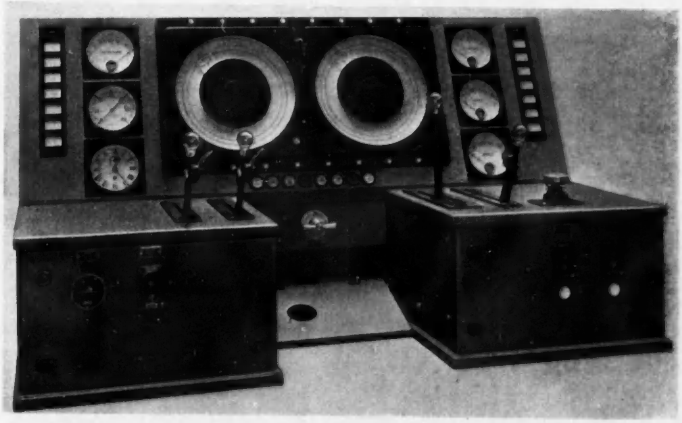


Fig. 23.—Control desk for dynamically braked winder for the Free State Development and Investment Corporation of South Africa.

A double-drum winder has been put into commission at the North pit of the Nantgarw Colliery of the National Coal Board. The drums are 14 ft. in diameter and will be used to wind coal, stone and materials from initial depths of 840 to 1,140 ft. and from final depths of 1,140 to 1,440 ft. The winder is fitted with special interlocking gear to work in conjunction with the intermediate landing gear in the pit shaft. The main coal winding will be carried out in the South Pit. The present winder which is equipped with a "sinking" drum will be suitably modified and altered to a cylindro-conical drum 12 ft. to 17 ft. in diameter. The winder, when thus modified, will have an output of 350 tons an hour and will raise 6 tons of coal from a depth of 1,440 ft.

For service in the Swansea area, there are being supplied to the N.C.B. nine reversible slipring haulage motors with an aggregate output of 4,200 h.p. These motors are arranged for dynamic braking and the control equipment for the largest unit, which is rated at 700 h.p., is also being supplied under this contract.

Equipment for the first of the four 4,200 h.p. A.C. winders for the Free State Development and Investment Corporation of South Africa is now being erected on site. Each winder is driven by two 2,100 h.p., 6·6 kV slipring motors, the control scheme employing the new form of dynamic braking which has been fully described in an earlier issue of this Journal.[1] It will be of interest to recall that dynamic braking is effected by the application of D.C. between two phase-terminals of the stator, the rotor resistor being used as a variable load. The system employed has the important advantage of affording precise torque control down to so low a speed that it avoids undue wear on the mechanical brake linings. Dynamic braking also reduces considerably the waste of energy entailed in reverse power braking. It is anticipated that the reliable performance of the new control system will afford some further saving of energy by permitting the regeneration of power over a wider range of the winding cycle.

The problem was to evolve a system of control in which the apparently conflicting conditions in the relationship between the strength of the D.C. field and the value of the rotor resistance were reconciled in such a manner that the excitation could be restricted at low speeds, for rope and shaft inspection, without forfeiting the braking power normally required at the same low speed, when a loaded or empty hoist is approaching the decking position.

Accordingly the control of both D.C. excitation and rotor resistance has been combined so that the response to the movement of the driver's lever is quite definite. In no case can the torque decrease when it should increase with increasing travel of the control lever, and vice-versa. Moreover, this system also affords a method of driving and reverse power braking control which gives maximum permissible acceleration or deceleration under any condition of load without relying on time mechanisms or current limiting controls for ensuring the safety of the hoist. The control desk for one of these dynamically braked winders is seen in fig. 23.

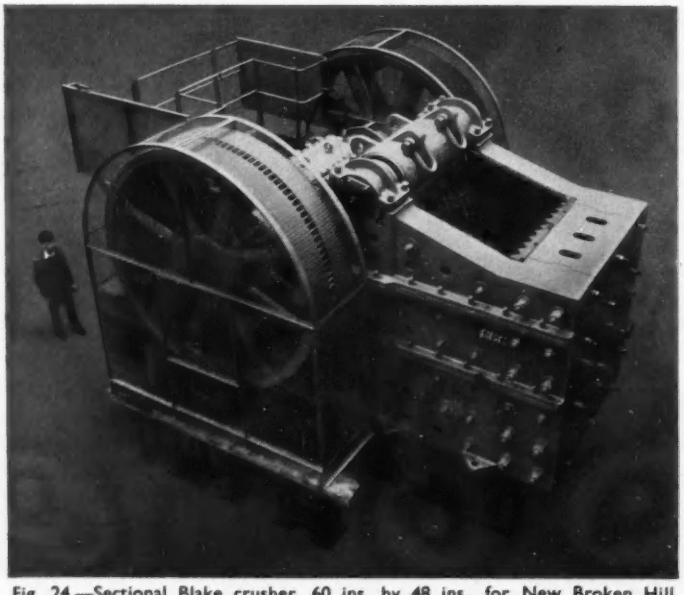


Fig. 24.—Sectional Blake crusher, 60 ins. by 48 ins., for New Broken Hill Consolidated Ltd., Australia.

Hammer Mills.

As an addition to the existing range of such equipment, the Fraser & Chalmers Engineering Works has designed a hammer mill fitted with a moving breaker plate, consisting

[1] "Principle and Features of a New Dynamic Braking and Motor Control System for A.C. Winders," by E. Friedlander, Dr.Ing., M.I.E.E., *G.E.C. Journal*, Vol. XVI, No. 4, October, 1949.

of a number of manganese steel plate sections mounted on heavy cast steel chain links, all of which move over cast steel head and tail sprockets in a manner similar to an apron feeder. The breaker plate is driven from a separate motor through a high ratio heliocentric gear.

The purpose of this breaker plate is to enable the mill to handle sticky material which would plug an ordinary hammer mill. One of these machines has been installed in Scotland to deal with wet bauxite. It reduces this material from a feed size of some 9 ins. and under to a product of minus $\frac{3}{4}$ in. square mesh at the rate of about 24 tons an hour, and is believed to be the first crusher of its type built in England.

A further machine of a smaller size has now been ordered to deal with the difficult Northampton ore. It will be required to crush wet iron ore from a feed size of 3 ins. to $\frac{1}{4}$ in. and under.

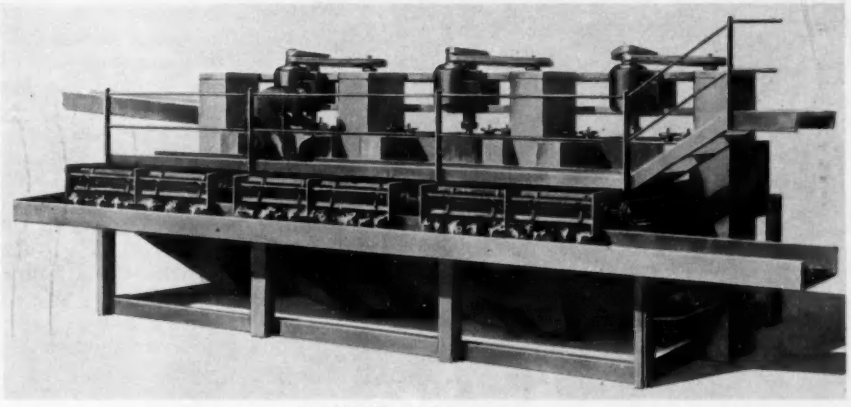


Fig. 25.—Froth flotation plant.

Primary Crushers.

A sectional 60 in. by 48 in. Blake crusher, just completed for the New Broken Hill Consolidated Ltd., of Australia, is shown in fig. 24. It was specially designed so as to be lowered down a small mine shaft 5 ft. 6 ins. square section with projecting runners. The steel side frames had therefore to be made in three sections with horizontal joints, the flywheels being in halves. The space available only permits the swing jaw to be lowered without its shaft, and, to avoid their having to be pressed together underground, the normal design has, in this case, been reversed and the swing jaw fitted with bearing bushes so that it swings on the shaft, held stationary by grips on the side members. The swing jaw is the heaviest single piece and weighs some 14 tons when bare.

The crusher runs at 120 r.p.m. and is driven through a Vee rope by a 200 h.p., 575 r.p.m. motor having a starting torque 225 per cent of full load torque. It is capable of reducing large boulders of hard ore to a product which can be adjusted to between minus 7 ins. and 9 ins. with a small percentage of oversize.

The advantage in being able to install these primary Blake crushers underground is that they enable the run-of-mine boulders to be broken to a size convenient for hoisting to the surface where secondary crushing and subsequent treatment can be carried out.

Pan Feeder.

An interesting pan feeder, 6 ft. wide by 16 ft. 6 ins. long, has been designed at the Erith Works for use in New Zealand. It is fitted with manganese steel pans and cast steel chain links, is capable of handling large pieces of rock and has an output of some 200 to 500 tons an hour. The speed of operation can be varied between 5 ft. and 15 ft. a minute by means of a fluid coupling which is suitable for an infinitely variable speed regulation between 400 and 920 r.p.m. on a constant torque drive. The drive also includes a Radicon worm reducing gear and a 25 h.p. motor which, together with the fluid coupling, are to be mounted on a combined bedplate. The function of the chain curtain is to baffle any rock which, during tipping operations, might bounce out of control over the delivery end of the feeder.

Moving Bar Finger Type Feeder.

A chalk crushing plant has recently been installed which incorporates a new type of finger bar grizzly feeder capable of handling 70 tons

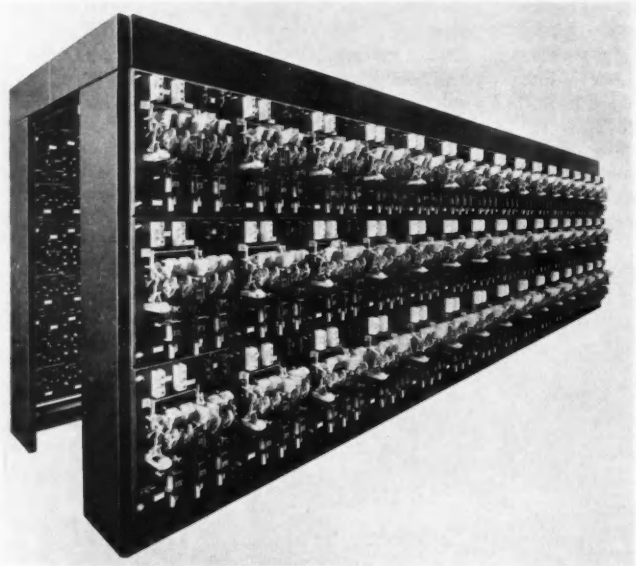


Fig. 26.—Main 250 volt contactor control board for the table motors for the continuous hot strip mill at the Abbey Works of the Steel Company of Wales.

an hour, the largest pieces of chalk being about 3 ft. by 2 ft. by 2 ft. This feeder, which is 4 ft. wide and 15 ft. long has given every satisfaction. In addition to its main purpose of regulating the feed to the crusher that follows, it also removes the fine material. The drive is from a 7½ h.p. motor having a variable speed from 725 to 480 r.p.m. The feeder is suitable for moderately large capacities which include big pieces. It is also capable of handling sticky materials.

Coal Preparation Plant.

Orders received for coal preparation plant include one for Nantgarw Colliery, South Wales, which will have a capacity of 350 tons an hour of run-of-mine coal, provision being made to extend the equipment so as to increase output to 700 tons an hour as the colliery is developed. The plant will combine the Chance sand flotation and froth flotation processes, the last named having a capacity of 60 tons an hour of minus $\frac{1}{16}$ in. small coal.

As a result of many years' development work, conducted both at the Research Laboratories, Wembley, and with a pilot plant erected at a colliery in South Wales, a process with high separating efficiency has been evolved by which small coal up to $\frac{1}{16}$ in. in size can be successfully cleaned. It is on the basis of the information and experience thus gained that the froth flotation cells have been designed.

As can be seen from fig. 25 the froth flotation equipment consists of a bank of cells in series, each having a square agitation box with a frothing chamber mounted in front. For simplicity the construction is in units of two cells, each agitation box having its own cruciform impeller driven from one vertical spindle motor mounted at the top of the assembly. A weir is provided to control the overflow from the agitation box to the frothing chamber. After the coal has floated to the surface of this

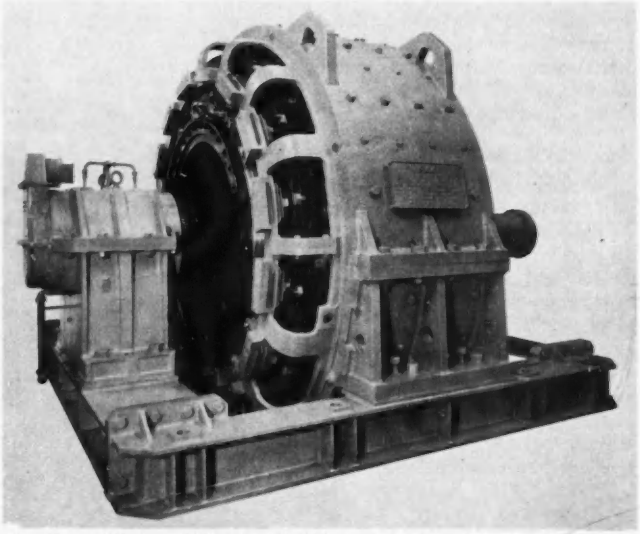


Fig. 27.—1,000 h.p., 565 volt, 0/30/60 r.p.m. main mill motor for Austral Bronze Co. (Pty.), Ltd., Sydney.

chamber the residue passes to the next agitation box, and so on throughout the series.

ROLLING MILLS.

The 45-inch slabbing mill in the Abbey Works of the Steel Company of Wales, for which the G.E.C. supplied all the auxiliary motors and part of the control gear, has been erected and put into commission. Much of the electrical plant and switchgear for the roughing and finishing mills at this Works, and for the pickling line at Trostre, is also on site. The table motor control board for the finishing mill is seen in fig. 26.

For the slabbing mill, which is designed to roll slabs up to 60 ins. wide by 8½ ins. thick from 20-ton ingots, there are sixteen motors, with a total output exceeding 5,700 h.p., for driving the auxiliaries. These include the ingot buggy, ingoing and outgoing tables, manipulators, screwdowns and slab shear. With the exception of the two machines driving the slab shear, all are mill type motors, supplied from two 9-machine motor-generator sets each of which is driven by a 2,000 h.p. synchronous motor arranged for direct-to-line starting.

In order to obtain very rapid response, the cascade exciter system of control is used for the ingot buggy and slab shear drives. This method of control, which was described in the review of progress in this Journal, January, 1950, is being extensively used by the Steel Company of Wales. Where very accurate and rapid control is required, as, for example, for the temper mill at Trostre and for the flying shear of the continuous hot strip mill at the Abbey Works, the cascade exciter will operate in conjunction with electronic amplifiers.

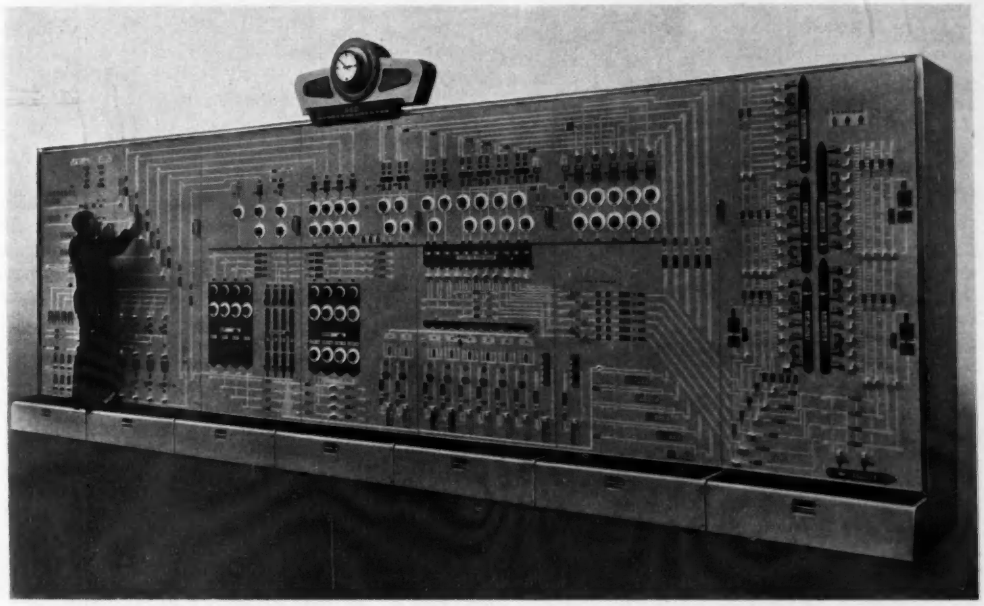


Fig. 28.—Signalling control board for the New Port grain elevator, Buenos Aires.

The rolling mill equipment for the 20-inch by 60-inch reversing mill for the Austral Bronze Co. (Pty.) Ltd., Sydney, New South Wales, has now been shipped. The main mill motor, seen in fig. 27, is rated at 1,000 h.p., 565 volts D.C. plus/minus 0/30/60 r.p.m. and is supplied from an 850 kW Ward-Leonard Ilgner set. In addition to the main drive this contract includes motors for all the associated auxiliary drives and the necessary control gear.

Orders received for rolling mill plant, during the period under review, include one for the complete electrical equipment for two strip mills at the Kynoch Works of Imperial Chemical Industries. Each mill will be driven by a 500 h.p., 420 volt, 250/265 r.p.m. D.C. motor, the two machines being supplied from a 1,000 h.p.

motor-generator set. For operating the auxiliaries a further eighteen A.C. motors with their associated control gear are being supplied.

In the review of progress in this Journal, January, 1950, reference was made in the section, " Electric Motor Developments ", to an improved design of totally enclosed fan-cooled D.C.

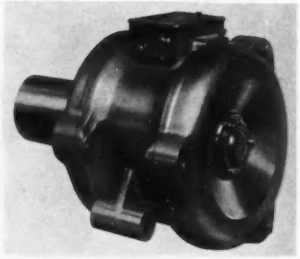


Fig. 29.—High torque squirrel cage motor for the drive of carding engines.

motor. Machines of this type are being supplied to the Steel Company of Wales, and a recent order for the drive of auxiliaries in the steelworks of the Wellman Smith Owen Engineering Corporation covers the supply of nineteen such motors aggregating more than 1,000 h.p.

INDUSTRIAL ELECTRIFICATION.

Grain Elevator Control.

Mention has already been made of the New Port grain elevator, Buenos Aires, in the Progress article in the *G.E.C. Journal*, January, 1950. With a total capacity of 150,000 tons it will be the largest of its kind in the Southern Hemisphere. The main contractors are Simon Handling Engineers, Ltd., of Cheadle Heath, Stockport ; the electrical equipment, comprising motors, transformers, switchgear, control boards, lighting and telephones, is being supplied by the G.E.C.

Particular interest attaches to the signalling control board, which will be the largest of this type ever installed. On it is shown, in mimic diagram form, the complete layout of the machinery from the point of intake where the grain is received by road, rail and barge, to the shipping quays where it is loaded in bulk into ocean-going steamers. Five ships can be loaded at a time, for which purpose five elevators, each of 600 tons an hour capacity, are employed together with 32 shipping conveyors housed in galleries along the quay.

The control board is of " Warerite " laminated sheet, built up of layers of paper impregnated with special synthetic resin. The mimic diagram is imprinted on the panel in four basic colours on a grey background and lies below the surface, so that it is permanently protected and is unaffected by moisture, insects or fungi such as are found in tropical climates.

The panel is seen in fig. 28, and as an indication of its size and capacity it may be mentioned that it is 28 ft. long and 9 ft. high ; there are 258 relays, 201 special selector switches, 151 push buttons, 445 indicating lamps, red, green and amber, and 2,200 outgoing terminals. Almost 25 miles of wire are used for the back-of-board connections.

Textile Electrification.

A new design of squirrel cage motor has been developed for driving carding engines, fig. 29. The machine is totally enclosed, rated at 1½ h.p., 960 r.p.m., and is hinge-mounted on a pin which passes through two lugs on the shell, so that belt tension is always satisfactorily maintained by the weight of the motor. To overcome the high starting inertia of the carding engine, the motor is specially designed to develop three times full load torque at starting and will hold this value of torque up to about 70 per cent of full speed. The heat capacity of

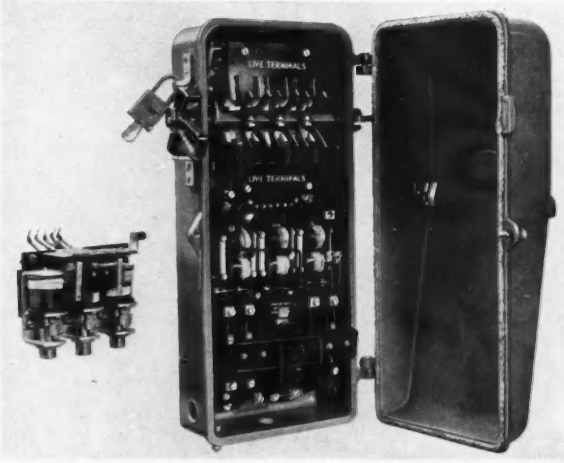


Fig. 30.—Direct-to-line starter for carding engine motor with overcurrent releases removed to show the saturable current transformers.

the windings is such that the motor can accelerate the heavy cylinder of the carding engine without overheating.

A special direct-to-line starter has been developed (fig. 30) which prevents the motor from being tripped during the starting period,

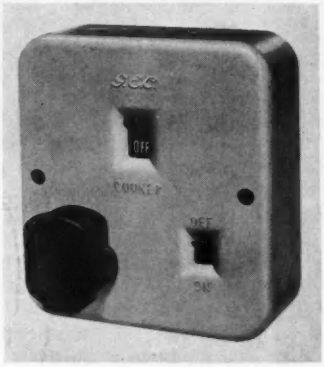


Fig. 31.—30 amp. surface mounting cooker switch with 13 amp. socket outlet and fused plug.

yet ensures proper overload protection when it is running. Accordingly the starter embodies low consumption saturable current transformers which supply the electro-magnetic over-current releases. In this way the necessary delay in tripping is obtained during the starting period. Integral with the starter is an isolating switch with three positions: "off" and "forward" for normal operation and a "reverse" to provide rotation in the opposite direction for grinding the cards. A padlock ensures that the isolating switch cannot be moved into "reverse" until the lock is removed by an authorised person; a mechanical interlock prevents the starter's being opened except when the isolator is in the "off" position.

A steady demand continues for loom motors and among the orders at present in hand mention may be made of one recently received from Khaipur State Textile Mills in Western Pakistan for five hundred ¾ h.p. machines in addition to one hundred and five industrial motors totalling over 600 h.p. together with the necessary switchgear.

Control Unit.

A new range of cooker control units is now in production (fig. 31). Four types with sheet steel cases are available, designed for 30 amps., 250 volts A.C. They are finished in cream stove enamel, suitable knockouts being provided for cables, and loose rubber bushes for use when the knockouts are removed. Flush or surface mounting types are available with flat pin fused plugs or round pin plugs and separate fuses which can be withdrawn from the front without removing the covers. Each unit contains a 30 amp. main switch and a 15 amp. sub-circuit switch, both of the "Mutac" type.

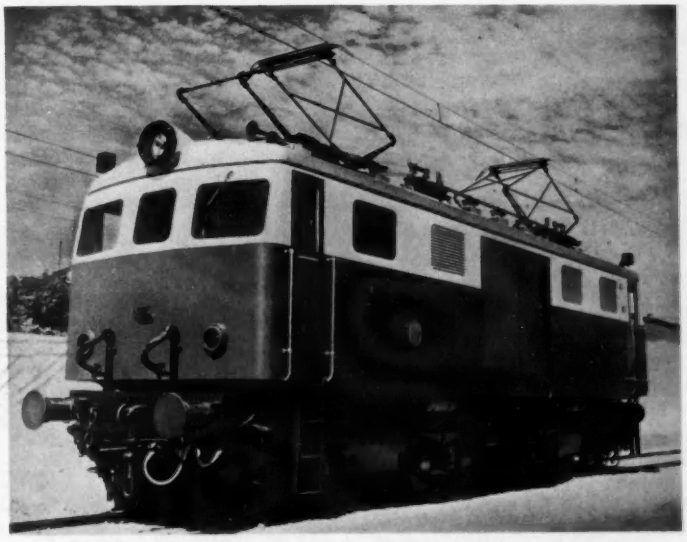


Fig. 32.—1,500 volt locomotive for the Estoril Railway, Portugal.

TRANSPORT.

Trolley Buses.

During the year further deliveries of trolley buses with G.E.C. electrical equipment have been made to Cardiff and Belfast as well as to Hobart and Launceston in Tasmania. All of these embody electric braking of standard type, which has given satisfactory service for many years.

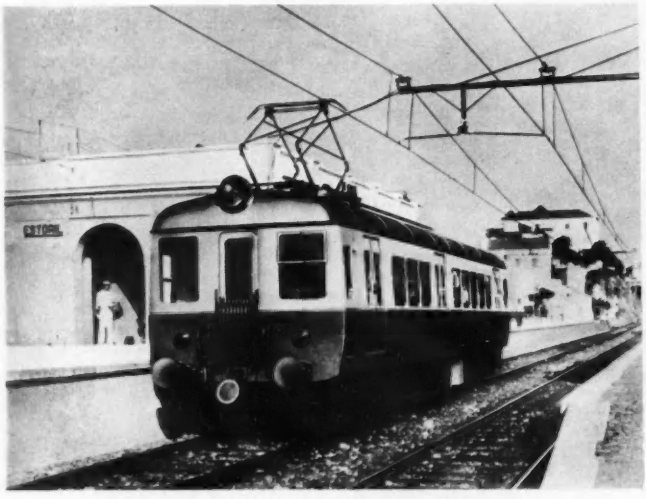


Fig. 33.—A motor coach on the Estoril Railway.

In view of the advantages accruing from this type of brake, development work has been undertaken in order to improve it still further and a new experimental model has been built. This brake has been in regular service on the bus system of the Reading Corporation and has given excellent results. The buses are fitted with the new standard 130 h.p. motor which is specially wound to suit the new system of control.

It must be understood that a trolley bus has no engine drag and is inherently free running. In consequence, if not provided with an electric brake, the wear on the brake shoes is excessive. Also, any electric brake provided must give a definitely limited braking effort to avoid damaging the back axle and transmission. Hence to obtain the maximum permissible braking effect the back tractive effort from the motor should be, so far as possible, constant regardless of the speed. Obviously this requirement cannot be met by any relatively simple equipment. In the experimental model at Reading, the ideal theoretical condition is much more closely approached than in the older equipments. The result is that a greater braking effect is obtained without exceeding the maximum permissible back tractive effort, which is determined by the design of the back axle.

Railway Electrification.

The motor coaches and locomotive for the Estoril Railway, Portugal, of which particulars were given in the *G.E.C. Journal* in January, 1950, have now been delivered and have been in regular service for some time. The equipments are for operation at 1,500 volts and represent modern post-war design. The locomotive and a motor coach are seen in figs. 32 and 33 respectively. The pantograph (fig. 34) which is of new design and lightweight construction, and which could not be completely tested at the Works, is operating satisfactorily in every way. By means of torque tubes the pan is arranged so as always to move up and down parallel to the mounting plane ; thus one end never tips up, as in the older types, should the other end be depressed. This has the advantage of giving slightly greater clearance in tunnels and under bridges.

The master controller for the equipment is also of interest as it is of the new pillar type,

Fig. 34.—Single pan pantograph for the Estoril Railway.

projecting from a narrow desk and situated to the side of the driver (fig. 35). This affords a very much more comfortable driving position than with the older type of desk mounted controller the brake control being on the driver's left side.

Another new type of controller worthy of note is that for use with the diesel-electric shunting locomotives which are being built for the Ceylon Government Railways (fig. 36). It is provided with a double set of handles which permit of control from either side of the cab without the necessity of changing handles. The controller is built on to a centrally situated case which carries various instruments and auxiliary control switches.

The generators, traction motors and auxiliary machines for these locomotives have passed their tests and delivery of the locomotives has begun and will be completed early in 1951.

The control gear for the 1,500 volt coaches for the Manchester-Sheffield-Wath section of British Railways is in course of delivery. The construction of the traction motors and auxiliaries has also begun.

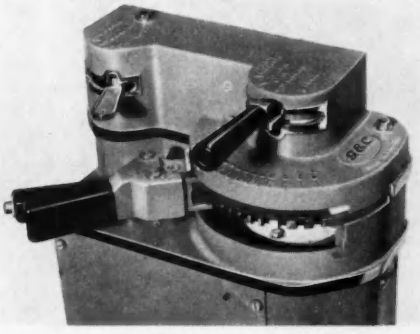


Fig. 35.—Master controller for 1,500 volt locomotive on the Estoril Railway.

The electrical equipment for the forty 3,030 h.p., 3,000 volt D.C. electric locomotives for the South African Railways has been designed and is now in course of manufacture. A number of components are completed and have undergone exhaustive tests, including, in the case of the main contactor, tests at the maximum operating voltage of 4,000 D.C. The first 505 h.p. traction motors are nearing completion and considerable progress has been made with the auxiliary machines, which include a 43 kW motor-exciter set and a 22 kW motor-generator set. Erection of the locomotives, which will be the most powerful in the world for 3 ft. 6 in. gauge, will begin early this year at the Works of the North British Locomotive Company.

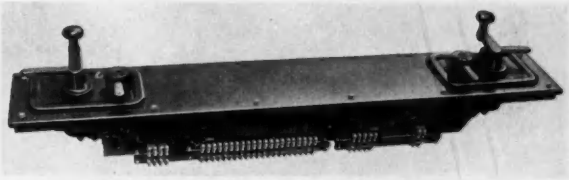


Fig. 36.—Master controller for diesel-electric shunting locomotives for Ceylon Government Railways. View before mounting in centre case, showing control positions.

Fixed Time Road Signal Controller.

A comprehensive article on vehicle-actuated road traffic signalling appeared in an earlier number of this Journal.[1] The Siemens and General Electric Railway Signal Co. Ltd. has always maintained that the greatest efficiency in traffic control can only be obtained by the use of the vehicle-actuated system. Although the general consensus of opinion confirms this view, it has become plain that a number of authorities abroad find the Fixed Time Cycle method attractive. A new Fixed Time Controller has accordingly been introduced which embodies many of the general principles employed in Autoflex equipment while occupying a much smaller space and having an essential simplicity which makes it easily understood and maintained. Perhaps the outstanding feature is the great flexibility of control and wide choice of mode of operation that the new controller offers, as indicated below.

The main features of the Fixed Time Controller (fig. 37) can be briefly summarised as follows.

1. Separate adjustment of the timing of each phase : 1 to 60 seconds in graduated steps.
2. Amber period separately timed and can be set between 1 and 10 seconds.
3. Hand control by push button.
4. Controller capable of giving colour sequence other than British.
5. Two phases can be combined for Late Start and Early Cut-off.
6. Controller capable of operation as local controller in flexible progressive schemes, or

[1] "Vehicle-Actuated Road Traffic Signals," by H. J. N. Riddle, A.M.I.R.S.E., Siemens and General Electric Railway Signal Co. Ltd., *G.E.C. Journal*, Vol. XVI, No. 4. October, 1949.

simple linking with existing installations of any type.

7. Pedestrian control by means of push buttons can be incorporated.
8. All-Red period 1 to 60 seconds in graduated steps.
9. All controllers fitted with a radio interference suppressor unit.
10. Space available for time switch.
11. Overriding switch for (10) when fitted.

The extensive practical experience of the S.G.E. shows clearly that the most flexible and reliable principle which can be employed to meet all requirements is that in which contactor relays are used for switching signal circuits. The relays are controlled from a safe low voltage sequence switch operating on 50 volts. As it rotates at each interval to switch on the signal relays, this switch also brings the appropriate timing control into play. For this reason the sequence switch and contactor relays have been adopted for the types of controller described.

The timing means employed in the Fixed Time controller is identical with that which has proved highly successful in the Autoflex vehicle-actuated equipment in recent years. An electrostatic condenser (not electrolytic) is charged to the pressure of the nominal 50 volt D.C. supply and in this condition prevents the flow of current through the anode circuit of a simple triode valve, which is of the high vacuum type as used in the domestic radio receiver. After a period which is determined by the value of the timing resistance, the condenser charge becomes sufficiently modified to allow current to flow through the associated valve and to affect an anode relay which signifies that the timing of the period is completed. The immediate effect of this is to operate the sequence switch one step and to recharge the condenser in readiness for timing the next interval.

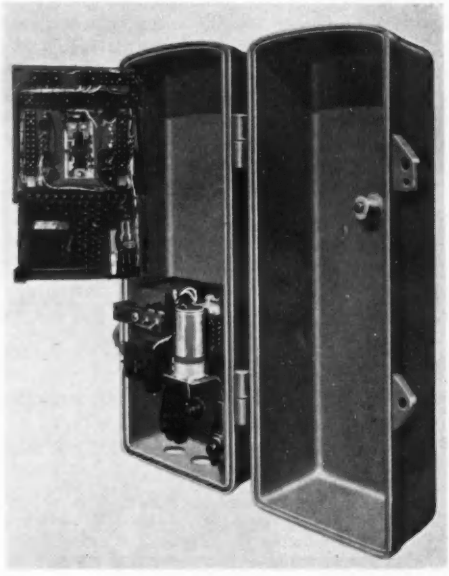


Fig. 37.—Fixed-time cycle controller for road traffic signalling.

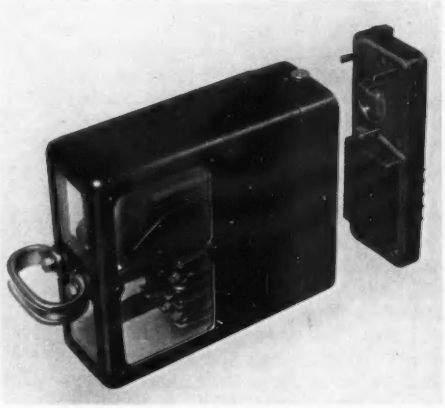


Fig. 38.—Single width D.C. plug-in relay.

Detachable Plug-in Relays for Railway Signalling.

Modern railway power signalling inevitably employs a variety of multi-contact relays involving the termination of large numbers of wires. The changing of relays in such installations, either under fault conditions or in the routine of periodical servicing, has required the disconnection and reconnection of many wires. Apart from the time occupied by such operations, there has always been the possibility of mistake which in a signalling system could have serious consequences. To avoid the need for disturbing wire connections and to ensure quick and accurate replacement, the Siemens and General Electric Railway Signal Co., Ltd., has introduced a complete range of detachable plug-in relays for railway signalling.

The relays are produced in two sizes only: single width 3½ ins. by 8 ins. high by 8½ ins. deep; double width 6½ ins. These two sizes

accommodate all varieties of functions and contact requirements with a compactness not previously attained, at the same time maintaining the usual standards of clearance and robustness associated with railway signalling relays.

The separate mounting base of high-grade moulding material is independent of the relay and contains the socket portion of the plug connection. This base is permanently fixed on a vertical rack or framework and the wire connections are soldered to the sockets. The plug connectors at the rear of the relay fit into these sockets so that the relay is removed by withdrawing it horizontally. When the relay is plugged into its mounting base, a special latch automatically locks it in position.

The connections to the relay contacts are also made by plug connections which extend from the rear of the relay and come into contact with spring sockets in the mounting base. The plug connectors are in a recess in the relay base, protected on all four sides by a wall of insulating material extending beyond the tips so as to prevent damage when the relay is being handled.

The relay contacts are of simple design and sturdy construction and the contact pressures and openings obtainable on both back and front contacts compare favourably with those of the conventional types used hitherto. Silver to silver-impregnated graphite is the contact combination usually provided, but others are available.

A one-piece case fits over the whole relay providing full protection with adequate facilities for inspection. A robust handle at the front allows good control in plugging the relay in and out and can also be used for hand transport.

The single width relay is available in contact combinations up to twelve front, and the double width up to 24 front. A single width relay is illustrated in fig. 38.

Fig. 39.—One of the new passenger lifts installed in Plantation House, in the City of London.

Passenger Lifts.

As a result of enemy action it has been necessary to replace three passenger lifts in Plantation House, in the City of London. The original lifts were of the geared, variable voltage type, with manually operated side-opening entrances, the depth of the car in each case being greater than its width. Careful consideration was given to the new scheme, as a result of which it was decided that two lifts could be installed which would be capable of dealing with the passenger traffic more expeditiously than the original three lifts.

The new lifts are of the gearless, variable voltage type, and are designed to run at 500 ft. per min. and to serve ten floors, involving a travel of over 100 feet. Each lift can accommodate 24 persons.

The increased speed has been an important factor in the efficiency of the new scheme, but its success has also been largely due to the inclusion of centrally opening power-operated doors on the lift cars which are wide but shallow in depth thus affording rapid entry and exit of passengers (fig. 39).

Operation of the lifts can be either by attendants or by the passengers and in both cases is entirely automatic. The system is such that all calls for direction of travel are answered in strict rotation and operation is so controlled that the two cars are effectively spaced so as to afford an even service. During slack periods either lift can be withdrawn from operation.

Schemes similar to that just described have been employed in the replacement of other war-damaged lift installations. Some of them have involved replacing four cars of the obsolete deep and narrow type by two cars with extra wide entrances of five and six feet. In all cases power-operated centrally-opening doors have been provided and the winding machines are of the gearless variable voltage type.

Magnetic Sweeps for Roads and Airports.

A robust and compact magnetic sweep has been produced to clear nails, swarf and similar iron or steel particles from roads and runways, thus protecting the tyres of vehicles and aircraft from damage.

The equipment, which is seen in fig. 40, embodies a 300 watt magnet, 24 inches wide, with an air gap adjustable up to $2\frac{1}{4}$ ins. It is energised by a self-contained, 18 volt lead-acid battery of 64 ampere-hours capacity. There is an on/off push-button switch on the handle and a red indicating lamp on the rear of the equipment which shows the operator when the magnet is energised and reminds him to switch it off when not in use thus avoiding unnecessary drain on the battery.

The equipment, which weighs about 2 cwt., is carried on four rubber-tyred wheels mounted on ball bearings to ensure smooth running. The apparatus is equally convenient for industrial use in picking up nails and similar small articles from the floors of workshops and packing bays.

Batteries.

Secondary batteries, or accumulators, are widely used in transport and for a great variety of industrial purposes. The cases are made of moulded plastic material and, during the last twelve months, in conjunction with the licensors, The Richardson Company of America, substantial improvements have been made in the quality of battery containers. This has been achieved partly by the incorporation of a special type of synthetic resin to improve the acid-resisting properties of the material and partly by the installation of an entirely new mixing plant. The special resin used is manufactured in the Witton Moulded Insulation Works and the chemical plant for this purpose was installed in October, 1949.

The mixing plant is entirely automatic, and by the elimination of the human element and the employment of elaborate controls, from the stage at which the raw materials are weighed, through the blending machines to the final masticating machines, a more homogeneous material is obtained and consequently containers of a more uniform quality. The plant employs a method of mixing which avoids the risk of excessive heating of the material, and tests taken since the new plant came into operation in May, 1950 show that an improvement of 10 per cent has been obtained in impact and tensile strengths, as shown on standard test bars. Impact tests on containers show an even greater improvement. Moreover, the new mixing plant ensures a much better dispersion of the special resin throughout the material and so imparts a better acid resistance to the containers than was possible by the old method. Finally, the new plant removes the bottleneck in production which previously existed, as it is capable of producing approximately double the tonnage at much lower labour cost. The production of containers by the new process is covered by British Patent Specification No. 637446.

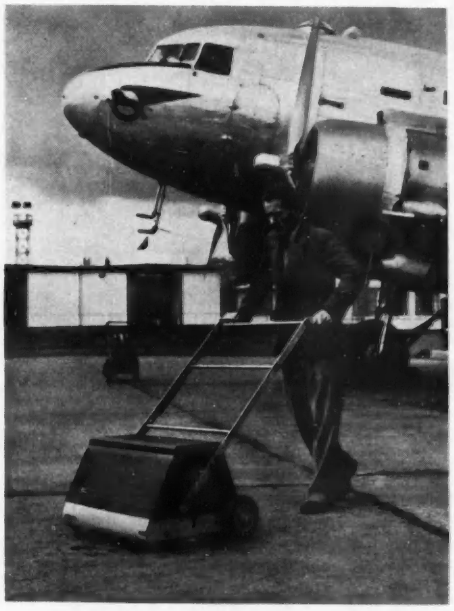


Fig. 40.—Magnetic sweeper in use at London Airport.

Marine Electrical Equipment.

An interesting contract has been received for the supply of mechanical conveying plant, and the necessary electrical equipment, for a self-unloading bauxite carrier for Reynolds Jamaica Mines, B.W.I., an associated company of the Reynolds Metal Company, of New York. The conveyors are being built at the Company's Erith Works, while the electrical gear, which includes two 100 h.p. slipring motors and two 20 h.p. squirrel cage motors and their associated control gear, will be manufactured at the Witton Works.

An order has been placed with the Company for the electrical equipment for the engine room of a new passenger-cargo ship for the Booth

Steamship Company, Ltd. The contract covers three 200 kW main diesel-driven generators, a 40 kW auxiliary generator and some 20 motors ranging from 3 h.p. to 73 h.p. for driving the ship's auxiliaries, together with a large amount of control gear.

During the period under review the single screw turbo-electric oil tanker, " San Salvador ", which was built by the Furness Shipbuilding Co., Ltd. for the Eagle Oil Shipping Co., Ltd., has completed her trials and is now in commission. She is a sister ship of " San Silvestre ", particulars of which were given in earlier reviews of progress in this Journal in January, 1949 and 1950. The Company provided the electrical propulsion and auxiliary electrical equipment for both these vessels.

Another vessel now in commission for which the electrical propulsion equipment has been supplied is " Sir Thomas Brocklebank," a pilot boat for the Mersey Docks and Harbour Board. Brief particulars of this boat were included in the review of progress in January, 1949, shortly after the receipt of the contract ; some further details of the equipment are worthy of mention.

It will be recalled that this is a single screw vessel with direct drive by a 920 h.p. single-armature D.C. motor supplied from two tandem generator sets driven by National Diesel engines. The main generators are each rated at 375 kW, 360 volts D.C. and the auxiliary generators at 80 kW. 220 volts. The isolator cubicles (fig. 41) are designed to allow either generator to

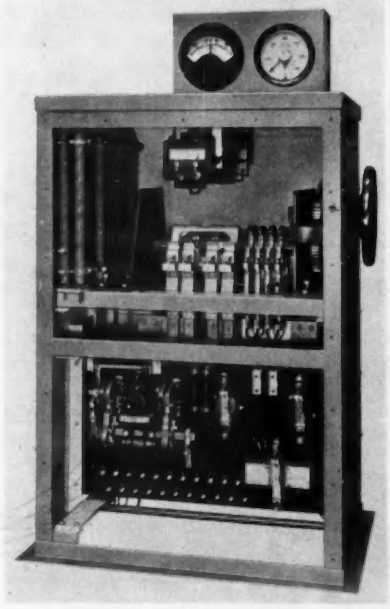


Fig. 41.—One of the two isolator cubicles for the diesel-electric pilot boat " Sir Thomas Brocklebank."

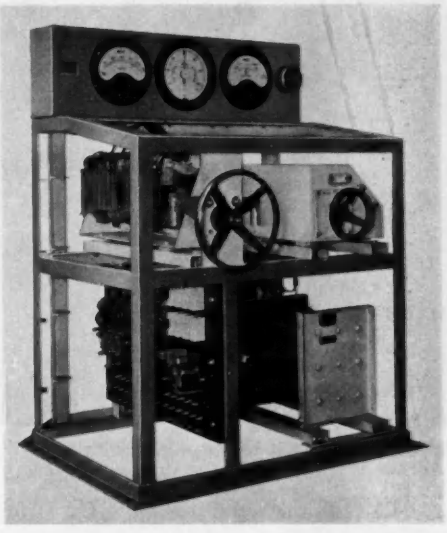


Fig. 42.—The control desk in " Sir Thomas Brocklebank," with front cover removed.

be used when running at reduced speed, control of the speed of the propulsion motor being effected from the desk (fig. 42) by field control of the main generators.

The control equipment has been simplified in the light of experience gained with earlier vessels of this type and is more compact and easier to operate.

Special provision has been made to give very small increments of speed at about one-third of normal speed for the purpose of keeping station. To do this, the operator has only to turn a handle and read a speed indicator. No delicately adjusted relays are used on this control which is of a simple mechanical character.

The switchgear is designed to enable the auxiliary generators and the standby generator to be paralleled on the main busbars. Provision is made for isolating the section of the board allotted to non-essential services, in an emergency, without interrupting essential supplies.

" Monarch of Bermuda " was built in 1931 and the G.E.C. manufactured and supplied the whole of the electrical equipment which

included turbo-electric propulsion gear, main and auxiliary generators, marine motors totalling over 3,000 h.p., lifts, lighting fittings, telephones, cooking equipment, fire alarm system and cabling. In 1947, the vessel was burnt out in dry dock and declared a total loss ; the damage to the electrical propulsion equipment and auxiliaries being from water and not from fire. The Company undertook a complete overhaul of the major items of electrical apparatus at their various works.

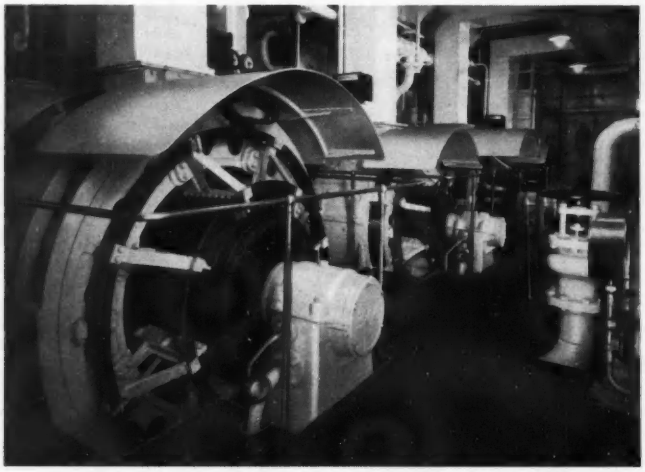


Fig. 43.—Four 220 volt auxiliary D.C. generators in the M.V. " Oslofjord."

The partially immersed 4,750 h.p. salient pole synchronous propulsion motors were opened up and coils removed from one slot on each stator for examination of insulation and laminations. Some stator slots were re-wedged and all the rotor coils were fitted with new insulating spools. All the stator coils were pressure tested at 5 kV and the rotors tested at 1·5 kV for one minute.

The main D.C. and auxiliary switchboards were rewired. The main line-contact circuit breakers and some of the instruments were returned to the Salford Works ; most of the switchgear parts were renovated at the Witton Works. Eight of the original thirteen lifts were reconstructed and modernised at the Northampton Works. The galleys were also reconditioned throughout and a considerable amount of new equipment supplied.

The vessel, which has been re-named " New Australia", is now in service as an emigrant ship.

The 16,500 ton " Oslofjord ", of the Norwegian American Line, plies between Oslo and New York and has been in regular service for some months. The overall length is 577 feet and there is accommodation for 576 passengers ; she replaces a vessel of the same name lost during the war. The G.E.C. has supplied four auxiliary 220 volt, 330 r.p.m. D.C. generators (fig. 43), two rated at 600 kW and two at 450 kW, all of them of the standard open type drip-proof marine pattern. The output is remotely controlled by electrically operated circuit breakers of the line contact type.

A 50-line automatic telephone exchange has also been installed, and there is a radio telephone

Fig. 44.—The 16,500 ton motor-vessel " Oslofjord " of the Norwegian American Line.

link for ship-to-shore communication when at sea. Passenger service in all parts of the ship, both by day and night, is provided by the standard marine luminous call system with indications at corridor stations and in the pantries.

The cabin class lounge and the dining-room are illuminated by cold cathode lighting which was adopted to emphasise the decorative architecture. Gold and ivory tubing is used, the A.C. supply being provided by a special generator set. In the lounge the ivory and gold tubes are separately switched to give attractive colour effects and for blending with the tungsten lighting when dancing is in progress. Indirect cold cathode lighting was adopted following the success of a similar installation on the motor vessel " Oranje ".

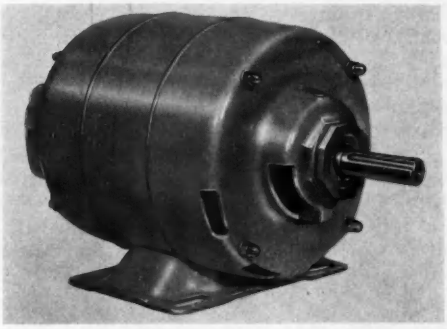


Fig. 45.—$\frac{1}{2}$ h.p. 1,440 r.p.m. split-phase induction motor typical of the new design of fractional horsepower machines.

ELECTRIC MOTOR DEVELOPMENTS.

FANS.

The 8 in. A.C. rubber bladed table and bracket fan, of which particulars were given in the review of progress in this Journal in January, 1950, has now been in large-scale production for almost a year. The new model entailed considerable development and extensive tooling which have been amply justified by the reception accorded to it both at home and overseas. It is encouraging to note that, despite the prejudice against fans of small diameter which exists in a number of overseas territories, many thousands of this model have been shipped to all parts of the world, including Malaya and other countries where extreme climatic conditions prevail. Orders for large quantities have also been received from dollar markets.

FRACTIONAL HORSEPOWER MOTORS.

A new range of induction motors from $\frac{1}{6}$ to $\frac{1}{2}$ h.p. at 1,440 r.p.m. (fig. 45) has been developed. These motors are available as split phase, capacitor start or 3 phase types. In the mechanical design, particular attention has been paid to ventilation : air is drawn into the machine at both ends and, after passing through the end windings, is discharged centrifugally at the outer edge of the bearing brackets, thus ensuring very efficient cooling which has made possible a considerable reduction in the size of the motor. The rotor is of die cast aluminium with integral vanes at both ends. Sleeve-type bearings are fitted, the sleeve consisting of a steel-backed bush with a white metal liner. The lubrication is by means of a felt wick feed. These motors can also be supplied with ball bearings.

The bearing brackets are pressure die-cast in aluminium ; the terminals are located in the switch end-bracket of which the terminal box forms an integral part and is suitable either for conduit entry or outgoing leads. The stator is of robust riveted construction ; the shaft extension, centre height and foot fixing centres conform to the proposed draft British Standard for Dimensions of Fractional Horsepower Motors. Motors with sleeve bearings can be foot mounted or resiliently mounted; machines with ball bearings are suitable for either foot or flange mounting.

An order from Canada is already in hand for 11,000 of these machines.

ELECTRONICS.

ELECTRONIC CONTROL.

An electronically-controlled printing press drive has been developed at the Hyde Electrical Works of Witton James, Ltd., and the first of these equipments is now in service at the Amalgamated Press, Ltd. (fig. 46). Precision speed control is available throughout the entire working range as well as special low speed facilities for inching.

Repeat orders have been received for electronic control equipments for motor drives from Triplex (Northern) Ltd. and also for two equipments for the Triplex Safety Glass Co., Ltd.

For the Head Wrightson Machine Co., Ltd., a further contract is in hand for complete electronically controlled driving equipment for a 300,000 lb. and three 100,000 lb. drawbenches, one of which is for export to Metal Manufacturers, Ltd., Port Kembla, Australia. Earlier orders for similar equipment, now being commissioned, cover two 100,000 lb. and three 25,000 lb. drawbenches.

An interesting application of electronic speed control to the drive of a veneer peeling lathe at the Forest Products Research Laboratory, Princes Risborough, has been described in an earlier issue of this Journal.[1] During the year

[1] " Electrical Progress and Development," *G.E.C. Journal*, Vol. XIV. No. 3. February, 1947.

three further equipments have been manufactured, one for Dehra Dun, India, and two for the Tyne Plywood Co., Ltd. The Dehra Dun equipment closely resembles the installation at the Forest Products Research Laboratory (fig. 47). The motor driving the lathe is rated at 60 h.p., 900 r.p.m., and is supplied from a motor generator set. The speed of this motor can be varied from 25 r.p.m. for inching up to 2,700 r.p.m., and is regulated by an electronic voltage-balance gear acting on motor-operated regulators. Two speed control systems are employed : one, actuated by a tacho-generator mounted on the lathe spindle, to regulate the rotational speed ; the other, the "take off" control, which is operated from a peripheral speed tacho-generator carried on a moving arm and driven by a roller. Rotational control is normally used in the initial stages of rounding the log and cleaning up flaws ; thereafter constant peripheral speed is maintained by the "take off" control in order to obtain the most satisfactory peeling.

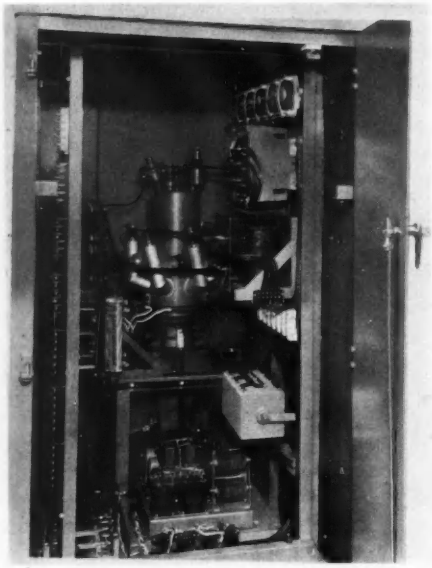


Fig. 46.—Electronic control equipment for a printing press drive for the Amalgamated Press, Ltd.

The two equipments supplied to the Tyne Plywood Co., Ltd. are of a similar, but somewhat simpler, type. The driving motors are 70 h.p. and 125 h.p. machines respectively and in both cases the peripheral speed is held approximately constant by means of a magnetic relay system operating through the usual regulators. All equipments embody inching and protective features.

Photo-Cell Equipment.

Heavy duty units have been designed for service in conditions where they may be subjected to rough usage and in atmospheres containing a large amount of dust. The cases are of cast aluminium with thick walls and wide flanged joints accurately machined for effective sealing. A separate terminal compartment gives easy access to the terminals without requiring removal of the main cover. The amplifier chassis incorporates a plug and socket system to facilitate quick replacement of the chassis for servicing purposes.

A standard photo-cell amplifier chassis is used (fig. 48) in conjunction with the Osram CMG8 photo-cell and the L63 amplifying valve. The necessary voltages for valve heater and high-tension supply are provided by a self-contained transformer with a primary winding tapped for

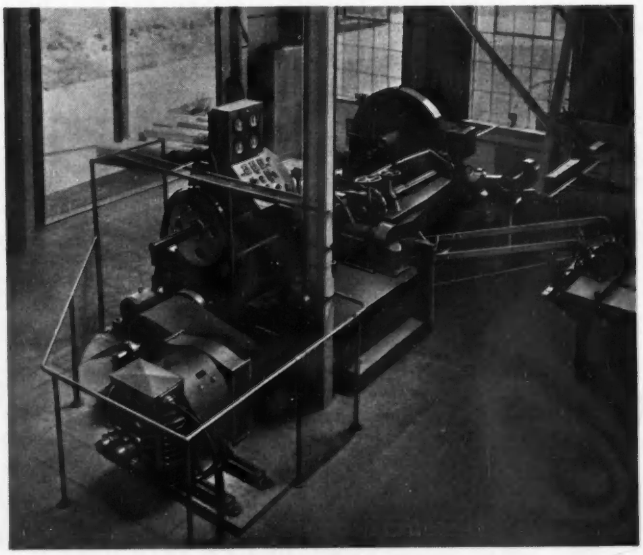


Fig. 47.—Electronically controlled veneer peeling lathe. The control desk is seen in the centre ; the main driving motor and tacho-generators are on the extreme left.

input voltages of 200/250 at 50 cycles. The amplifying valve operates a sensitive relay the contacts of which give a single-pole changeover action and will carry up to 50 watts at 440 volts, 50 cycles. When required, an additional set of contacts can be fitted to the relay to permit control of two entirely independent circuits.

The unit is designed to operate with an illumination of 5 ft. candles, but double this amount is preferable due to the possibility of dirt on the projector and amplifier windows which is liable to obscure the light.

The chassis is mounted on a substantial sub-base which also incorporates a multi-way socket to which the amplifier is preconnected. The sub-base is retained in the amplifier case by three bolts. A terminal block in the lower compartment is connected to the amplifier by means of a multi-pin plug. Thus by withdrawing this plug and unscrewing the three sub-chassis fixing bolts the complete chassis can be rapidly removed from its case and a spare one fitted.

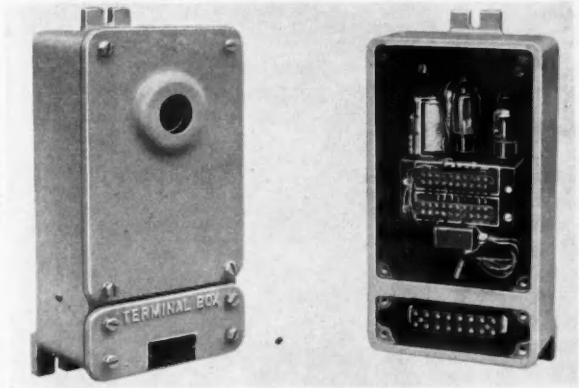


Fig. 48.—Heavy duty photo-electric cell amplifier ; exterior view (*left*), and with cover removed (*right*).

In the centre of the chassis cover there is an armour plate-glass window, sealed with a rubber gasket, well recessed to minimise possible damage. The case has three lugs for vertical mounting and suitable adjustment for correct alignment.

The lamphouse is similar in construction to the amplifier unit. The case is identical except that there is a bi-convex lens in the main cover for focusing the light ray. There is a removable sheet steel base with a supporting bracket for the lampholder which carries a 12 volt 24 watt lamp supplied from a step-down transformer. Provision is made for both axial and vertical adjustment of the lamp to compensate for slight variation in structure and to permit accurate focusing. Adjustment is available for fine alignment of the unit after the cover has been bolted in position.

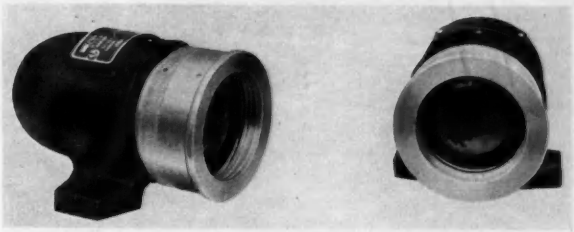


Fig. 49.—Two views of the 12 volt projector lamp.

Photo-electric counting and control equipment is frequently required to operate under adverse conditions such as an atmosphere containing chemical fumes or at a high temperature, both of which have a deleterious effect upon silvered reflectors. To overcome this, the projector has been redesigned to incorporate a lens in place of the reflector (fig. 49). At the same time, provision has been made for fitting infra-red screens carried in a removable extension of the front rim. This reduces the temperature of the screen itself and lengthens its working life.

VALVES, RADIO AND TELECOMMUNICATIONS.

Among recent developments in the application of wire telephony is a portable picture-telegraph equipment for the transmission of photographs, drawings and maps over telephone or equivalent circuits. The apparatus now being produced for this purpose provides the highest definition possible within the limits prescribed by the Comité Consultatif International Télégraphique.

The demand for remote supervisory control equipment continues, and a number of new installations is of particular interest.

Several systems supplied recently to Canada employ " chopped " 90 c/s signalling, and indications of meter readings can be received over the system. When required, cyclic metering can be used, the readings being

Fig. 50.—A new central battery cordless lamp-signalling switchboard equipped for four exchange lines and ten extensions.

indicated automatically in sequence for a definite period.

The Southern Region of British Railways has been supplied with a D.C. signalling system, consisting of four separate 2-wire tandem systems with two telephone circuits. Three substations are at present controlled in each tandem system, which can accommodate up to twenty substations if required.

A new range of C.B. cordless switchboards has been introduced for small business offices. As shown in fig. 50, the equipment is housed in an attractive polished wooden cabinet which harmonises well with modern office furniture. Lamp signalling is employed, and the switchboard is available in capacities ranging upwards from 1 junction with 3 extensions.

Smaller ships of the British fleet are being supplied with 25-line rotary, non-multiple, automatic telephone exchanges. In addition, when in harbour, an attendant's cabinet enables telephone connections to be made with shore exchanges.

New magnetic alloys have improved the performance of the loading coils used in telephone equipment, both in respect of electrical performance and reduction of physical size. One new alloy (Gecalloy III) gives a higher permeability, lower losses, and greater stability both with time and with superimposed electrical currents than the materials used previously. Toroidal cores made from Gecalloy III are now used extensively in telephone filters, and in all types of inductances from audio to the lower radio frequencies.

The now familiar magnetic tape recorder is still finding new uses. To meet the requirements for multilingual announcements at Parkeston Quay, a special recorder and reproducer (fig. 51) has been installed. The various announcements are recorded on separate spools of tape, which are stored, and played as required. For simplicity the tapes are threaded individually by hand, but elaborate precautions are taken with preliminary monitoring and automatic controls to prevent possible errors. The unit has been designed as an addition to a standard loudspeaker installation. Each tape plays for a maximum time of six minutes and has usually been recorded in a studio. In an emergency, however, tape recordings can be made using the equipment itself. Similar arrangements are being made in connection with the installation of loudspeakers now being

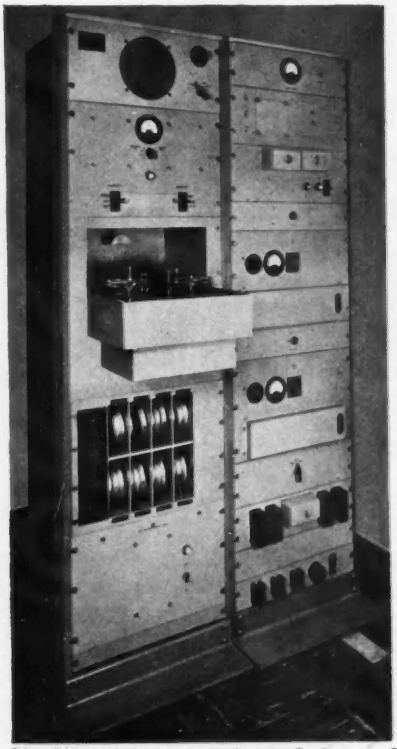


Fig. 51.—Magnetic tape recorder at Parkeston Quay, Harwich, British Railways.

carried out on the "Hook Continental" boat train.

Progress in radio communication continues to be rapid, and perhaps the most spectacular advances have taken place in the development and application of multi-channel links. The success of the scheme for extending the television service to the Midland area has been largely due to the reliability in service of every component part of the whole project. The G.E.C. equipment supplied for the London-Birmingham Radio Relay Link has been operating with complete success since the opening of the service on 17th December, 1949. The final installation is now being made to provide simultaneous two-way working between London and Birmingham, the radio equipment being housed in cabins at the top of the relay towers.

Special amplifiers have been made for the coaxial cable link which will extend the television service from Birmingham to the Manchester area. These amplifiers, made to a design of the Post Office Engineering Department, have a specified performance in the working range of 60 kc/s—4·34 Mc/s. They provide a high degree of impedance-matching to the cable and greatly reduce the problems of echo and phase correction. Equalisation for the attenuation/frequency characteristic of the coaxial cable is effected by the amplifiers themselves, thereby enabling good values of signal-to-noise ratio to be obtained over the lower part of the video-frequency spectrum. Nineteen repeater stations are used at intervals of approximately six miles.

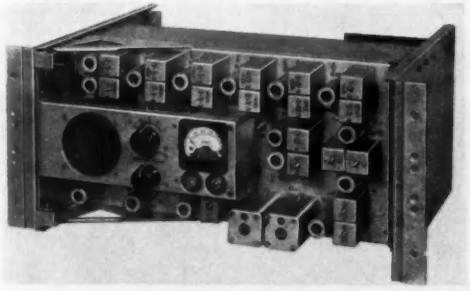


Fig. 52.—Amplitude-modulated V.H.F. transmitter, BRT.179, with front cover removed.

Further tests have been made of the performance of the 24-channel V.H.F. frequency-modulated system, and such equipment is being supplied for telecommunication networks in Nyasaland and Southern Rhodesia. A special feature of these schemes is that the radio stations will be unattended and will be fitted with automatic stand-by equipment and remote fault signalling.

A precision radio control system using seven channels has been developed on behalf of the Royal Aircraft Establishment; seven remote servo units may be independently controlled over land line or radio links. The method used is based on the measurement of the phase displacement between a low frequency tone in each channel and a reference tone. The accuracy of control is $\pm 2\frac{1}{2}°$ in 360° for radio transmission, or $\pm 1\frac{1}{2}°$ in 360° for ideal line transmission.

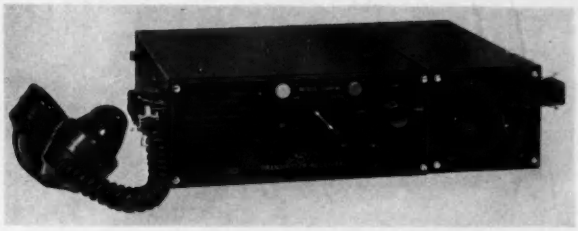


Fig. 53.—5 watt amplitude-modulated, V.H.F. transmitter-receiver with rotary transformer power unit.

Further telecommunication systems, suitable for a wide variety of modulation techniques, are being developed and these will handle larger numbers of speech, music and telegraph channels. Operation will be on micro-wave frequencies; versatility, reliability and ease of main tenance are important features of the design.

Among the more interesting developments in single-channel links is a range of fixed station receivers and transmitters giving high performance and reliability under severe climatic conditions. Such equipment is being supplied to the Malayan Union Police, and fig. 52 shows the type of construction used both for the receivers and the transmitters. The signals transmitted by the system may be either amplitude-or frequency-modulated. The power output from the transmitter is 8 to 12 watts, depending on the frequency, and the receiver noise factor is less than 4 db at 100 Mc/s.

In mobile V.H.F. equipments, the demand for lower power consumption has led to the development of a small transmitter-receiver unit covering the frequency range of 71 to 184 Mc/s. The transmitter power output is 3 to 5 watts, and the receiver noise factor is

6 db at 100 Mc/s. A typical unit, intended for tropical use, is illustrated in fig. 53. The weight of this particular equipment is 25 lbs. and its size $14\frac{3}{4}$ ins. by $4\frac{1}{4}$ ins. by $10\frac{3}{4}$ ins. Such units are designed for mounting behind the dashboard

have found that the application of a direct current between the earth and pipe can materially reduce corrosion in a number of cases. Current density must, however, be carefully controlled to suit ground conditions and other factors.

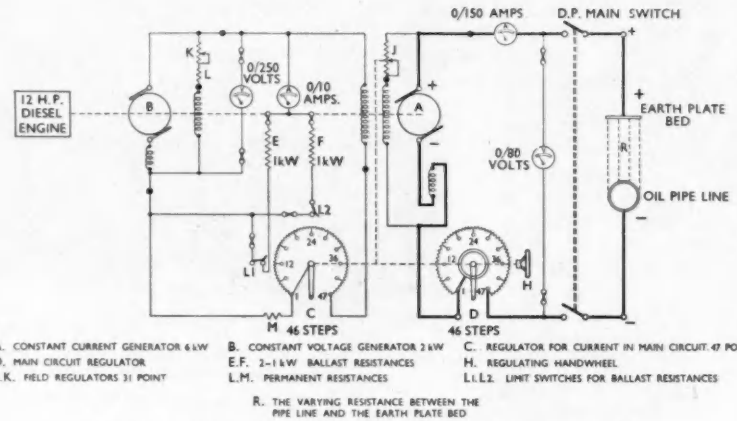

0/150 AMPS
D.P. MAIN SWITCH
12 H.P. DIESEL ENGINE
0/250 VOLTS
0/10 AMPS.
EARTH PLATE BED
0/80 VOLTS
OIL PIPE LINE
1kW
1kW
46 STEPS
46 STEPS
A. CONSTANT CURRENT GENERATOR 6 kW
B. CONSTANT VOLTAGE GENERATOR 2 kW
C. REGULATOR FOR CURRENT IN MAIN CIRCUIT. 47 POINT
D. MAIN CIRCUIT REGULATOR
E.F. 2-1 kW BALLAST RESISTANCES
H. REGULATING HANDWHEEL
J.K. FIELD REGULATORS 31 POINT
L.M. PERMANENT RESISTANCES
L1.L2. LIMIT SWITCHES FOR BALLAST RESISTANCES
R. THE VARYING RESISTANCE BETWEEN THE PIPE LINE AND THE EARTH PLATE BED

Fig. 54.—Diagram of cathodic protection circuit for oil pipe lines.

of a car and can be supplied with vibrator power packs, or rotary converters.

Investigations have been made to determine the useful service area of mobile communication systems using a frequency of 465 Mc/s. Satisfactory communication over ranges of 8 to 10 miles was obtained when transmitters were situated on a high open site or on a site in the centre of London. It was also found possible to transmit intelligible signals through curved railway tunnels up to a mile in length. In comparison, simple low-powered equipment such as might be used in a "walkie-talkie", gave ranges of $\frac{1}{2}$ to 1 mile in the open, and 60 to 100 yards inside a brick and steel-framed building.

In an earlier issue of this Journal reference has been made to the work accomplished in connection with the extensive radio communication system for the new Middle East pipe line.[1] It is thus of interest to record that a constant current generating plant has recently been developed to afford cathodic protection from corrosion for such pipe lines.

The pipe consists of steel tubes and, due to the pressure at which it operates, very high ring stresses occur in the metal. Hence it is important that corrosion of the steel should be kept to a minimum. Engineers working on the pipe line

The problem, therefore, is to provide equipment which will maintain the current between earth and pipe sensibly constant as the resistance

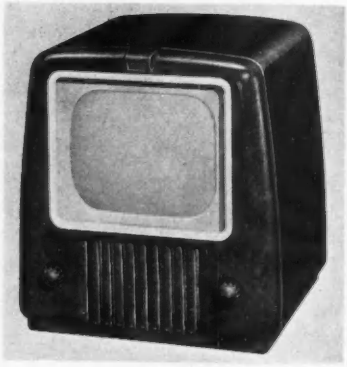


Fig. 55.—The new table model television receiver.

of this path varies with weather conditions and for other reasons. Moreover, since the pipe lines run for great distances through sparsely populated country, the equipment must be extremely reliable and easy to maintain.

The equipment consists of two D.C. generators driven at constant speed by a 12-h.p. diesel

[1] "Electrical Progress and Development," *G.E.C. Journal*, Vol. XVI. No. 1. January, 1949, p. 31.

engine which draws its fuel from the pipe line. The generator which supplies the load circuit has two fields, one self-excited the other separately excited from the second machine which is, in effect, an exciter (fig. 54). The characteristics of the two machines are such that the load resistance can vary over a wide range without materially altering the load current; further, an accidental short circuit on the load circuit does not cause a heavy current to flow, nor does an open circuit produce a serious overvoltage.

The current in the load circuit is pre-set to the value required by the operation of a single hand-wheel which actuates three regulators which are mechanically coupled and so proportioned that the necessary adjustments enable the load current to be varied from 5 to 120 amps. in 47 steps. From this it will be seen that the control is extremely simple and that there are no delicate relays or moving parts in the control gear requiring maintenance or which might be affected by the severe climatic conditions in which the plant has to operate.

Since a very lightly loaded diesel engine is liable to give trouble due to the sooting up of the cylinders and injection nozzles, arrangements are made to switch in an artificial load of one of two kilowatts when the plant is operating at the lower load settings.

The aspect of radio communications that is of particular interest to the domestic consumer is the design of new receivers, both for radio and television. During the year under review, a new table model television receiver, the BT2147, has been developed (fig. 55). This is an A.C./D.C. set suitable for mains supplies of 200-250 volts, incorporating a 9 in. aluminised cathode ray tube with permanent magnet focusing. Special attention has been paid to good focusing, high stability time bases, efficient noise suppressors, and spot limiting circuits. A sub-chassis assembly, which plugs into the main chassis, can be readily removed for general servicing. By interchanging two such assemblies the set can be adapted for reception on either the London or the Midland frequency.

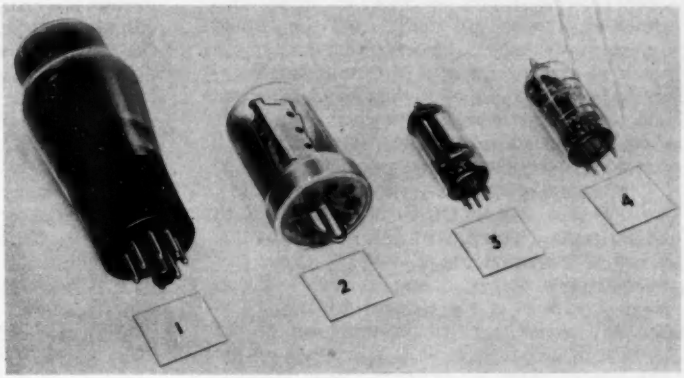


Fig. 57.—Receiving valves: No. 1 has the bakelite "octal" base. No. 2, now obsolete, has the all-glass B9G base; No. 3, the miniature type with all-glass B7G base. No. 4 has the all-glass B9A base.

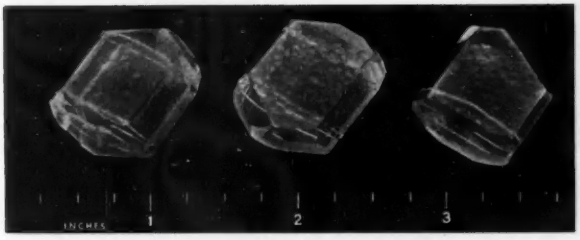


Fig. 56.—Synthetic quartz crystals.

Continuing progress in the applications of radio techniques makes increasing demands on the performance and versatility of the various components used. One such component is the piezo-electric crystal, and research into the synthesis of quartz crystals has shown marked progress during the past year. Crystals, such as those shown in fig. 56, have been grown in about 10 days by the temperature gradient method, using crushed crystalline quartz as the starting material. Z-cut quartz "seeds" were used, and it can be seen that sound piezo-electric material has been deposited during the whole growth cycle. The isothermal method of quartz synthesis, using silica glass as the starting material, is still of particular value owing to the speed with which a satisfactory crystal can be obtained. There is now a real prospect that much larger crystals will be grown when new and larger equipment has been put into service.

There is no doubt that valves, whether crystal, receiving, or transmitting, constitute the most important group of components used in radio systems. Some mention was made last year of both the silicon and germanium crystal valves. An important advance affecting the use of germanium crystal diodes and triodes has been the development of a source of supply in this country. Until recently, it was necessary to import this somewhat expensive material from the United States. It was known, however, that germanium occurred in minute traces in certain Northumberland coals and, in 1946, the G.E.C. Research Laboratories began to investigate this source as a possible means of supply. Research work showed that certain flue dusts contained up to 1 per cent of germanium and, after extensive investigations carried out in co-operation with the Research Department of Johnson Matthey & Co., a successful process was developed for the extraction of germanium from this source. Large quantities of the element are now commercially available either in the form of the metal or of its oxide.

As the development of the germanium diode and triode proceeded, it was found that for some purposes very pure germanium is required, while at other times a minute but accurately controlled trace of certain impurities is needed. These materials have now also become available as a result of the co-operative work between the G.E.C. Research Laboratories and Johnson Matthey & Co., and are being used in the production of germanium rectifiers and in experimental work on crystal triodes.

Germanium rectifiers are now in large-scale production at the Radio and Telephone Works, and are replacing thermionic valves in certain positions in television receivers.

The development of the germanium triode has not yet reached a stage at which large-scale production is visualised. Improvements which make completely hermetic sealing possible have, however, been made in the design. The new version is smaller than the original one, and overall size has been further reduced by the elimination of valve holders, the triode being soldered directly into the circuit.

These developments have not lessened the demand for the more conventional valves, and several interesting developments in this field have been made. Fig. 57 illustrates the general changes that have taken place in the design of receiving valves. When working at ultra-high frequencies, serious losses and "drift" are caused by the long internal leads and plastic caps used in earlier valves (No. 1). This has led to the development of the "all glass" valve, of which No. 2 is an example.

When such complex devices as radar, which may incorporate hundreds of valves, were first installed in aircraft, it became apparent that smaller components would have to be designed. This has led to the production of "miniature" valves such as No. 3. Although, after the war, there was a tendency to revert to larger valves, the revival and extension of television services

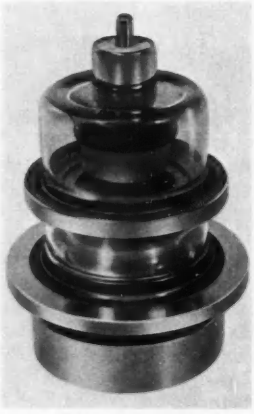


Fig. 58.—E.2012 transmitting valve.

Fig. 59.—E.2013 transmitting valve.

and the urgent need for economy in materials have again established the " miniature " valve for more general use. No. 4 is a further variant of the " miniature " valve for use when more than 7-pin connections are required, either for multi-electrode valves like the triode hexode, or where more than one connection is made to an electrode to reduce radio frequency losses still further.

Complete ranges of valves for battery-portable, A.C.-operated, and A.C./D.C.-operated broadcast receivers have been developed in the " miniature " size, and are now in mass production.

A further valve type, now in general use for television receivers, is the EHT rectifier U37. This is a small tubular valve, 12 mm. in diameter and 45 mm. long, and the directly-heated cathode consumes only 0·2 watt. The U37 has flexible leads so that it may be soldered directly into the circuit which produces HT power for the cathode ray tube, either from the line fly-back voltage or from an R.F. oscillator source.

The A1714 is another " miniature " valve designed to give very low inter-electrode capacities and high mutual conductance. This valve is for specialised low noise wide-band operation.

One of the valves used for rectifying high alternating voltages, type E2151, has been specially designed to operate in oil and can withstand a peak inverse voltage of 150 kV and give an output of 1 mA max. Although not a true " miniature ", this valve is nevertheless quite small, having an overall length of 14 cms.

With transmitting valves, the need for high power at high frequency provides many problems of design and engineering. The particular design problem, arising out of the need to minimise lead inductance, has been solved by the further development of the disc-seal type of construction. While a low inductance and a good H.F. performance can be obtained with the original disc-seal, the nickel-iron alloy used for the seal itself has low thermal conductivity, even when copper plated, and when used as a grid seal imposes a severe restriction on the power which can be dissipated in the grid. A seal has now been developed which has short axial length, and therefore good H.F. performance, but which, at the same time, has a high thermal conductivity. This new seal comprises a copper plate, attached to rings of nickel-iron alloy to which the glass is sealed. In addition, the construction is strong and the copper plate can be machined after the glassing operation ; the close and accurate clearances required in H.F. valves can thus be obtained. A seal of this type is used in the E2012 (fig. 58), a valve incorporated in the ground transmitter of equipment used by civil aviation authorities for measuring distance. This valve gives a peak pulse power output of 15 kW at frequencies up to 1,500 Mc/s, with a high duty cycle. The corresponding valve for airborne use is the E2013 (fig. 59), which gives 5 kW pulse output up to 1,500 Mc/s.

Research and development work on hydrogen thyratrons for use in radar modulators has culminated in the production of two types of high-power valves having long life. The E2158 (CV456), shown in fig. 60, normally operates at 15 kV and gives an output of 1·5 megawatts at a repetition rate of 500 p.p.s. It is a replacement for the CV12 mercury vapour thyratron and avoids the disadvantages, such as the necessity for temperature control and prolonged warming up, of the mercury vapour types. The other valve, E2205 (CV2158), although only

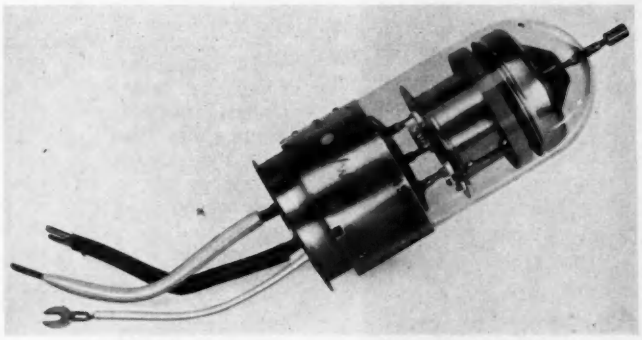


Fig. 60.—Hydrogen thyratron, type E.2158 (CV. 456).

slightly larger in dimensions than the E2158, has a considerably higher rating with an output of 3 megawatts at repetition rates of 1,000 p.p.s. or more.

A major difficulty in the earlier attempts to produce hydrogen thyratrons was the decrease in the hydrogen pressure during operation. This restricted the life to a value which was undesirably short in valves of moderate power, and was totally inadequate in the high power valves already referred to.

A means was therefore developed by which the hydrogen in the valve can be replenished when necessary, and this has made possible the large-scale production of hydrogen thyratrons with a long and reliable life.

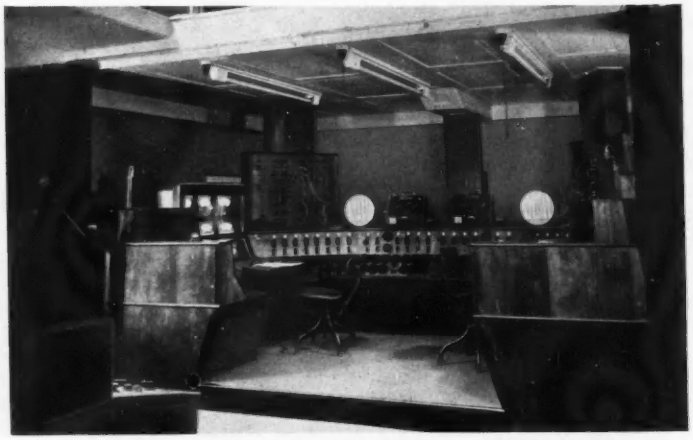


Fig. 61.—Test table for cathode ray tubes at the Research Laboratories, Wembley.

Fig. 62.—Noise measurement of an arc lamp in the echo-free chamber.

Development of cathode ray tubes has continued throughout the year. The high quality of G.E.C. cathode ray tubes is largely due to the rigorous tests carried out on the product. Much attention has been given during recent years to the methods used for testing all the types of cathode ray tube manufactured by the Company. Close collaboration between the Research Laboratories and the manufacturing units of the Company has resulted in the establishment of a number of new techniques for testing both the life and the performance of cathode ray tubes. The experience gained in this field over a number of years has now led to the construction, at the Research Laboratories, of a new test table which can be readily adapted for testing all known types of cathode ray tube. In addition, new life test equipment capable of operating at higher voltages has been designed and built to test the larger, 12-inch, cathode ray tubes which now form the greater proportion of the Company's product.

On the test table shown in fig. 61, a wide range of parameters may be measured with considerable rapidity and to a high degree of accuracy. The normal static tests may be per-

formed on four tubes at a time if side-by-side comparisons are needed. Numerous test patterns are also available, including those for H.F. and L.F. linearity tests, 3 Mc. brightening pulses for deflection defocusing tests, wedge patterns for spot size measurements, and picture signals from Alexandra Palace or from local monoscopes are also used. The brightness of the cathode ray tube screen is measured by means of a Salford

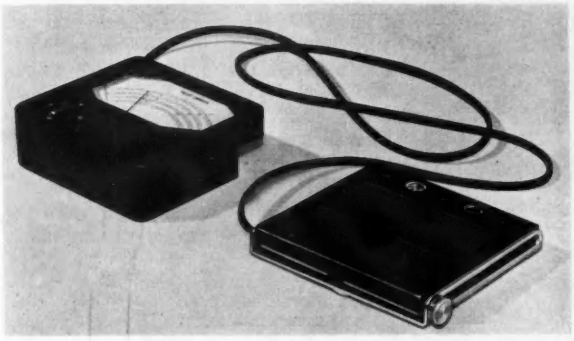


Fig. 63.—General purpose illumination meter.

universal photoelectric photometer. The power supplies, which are electronically stabilised and continuously variable, and the associated equipment, are mounted in racks on a specially constructed gallery above the test table consoles.

A brief description was given last year of an echo-free room being built at Wembley for the study of acoustic problems. This is now complete and many problems of noise measurement have been studied. Fig. 62 shows a 150 ampere double negative arc lamp undergoing test. Any type of object may be tested provided it will pass through the door (6 ft. by 2 ft. 10 ins.) and does not weigh more than 350 lbs. This test service is now generally available within the Company.

MEASURING INSTRUMENTS.

The new range of switchboard instruments that has recently been produced includes wattmeters, power factor meters, frequency indicators, synchroscopes, voltmeters and ammeters. These are all obtainable in the 3½ in., 6 in. and 8 in. round patterns. In addition, four models of each instrument are available, since the dial may either be projecting or flush, all-glass or protected. The movements and magnet systems of all these new instruments incorporate the latest improvements in materials and design. The 6 in. scale portable instruments used for measuring voltage and current in D.C. circuits, and those measuring voltage, current and frequency in A.C. circuits have also been re-designed.

A more specialised instrument, which also incorporates a new indicating meter, is the general purpose illumination meter (fig. 63). This has been developed to satisfy the demand for a portable light-measuring instrument which yet achieves a high degree of accuracy. The instrument consists of a 4 in. scale indicating microammeter and a separate photocell unit, and covers four ranges (0-3, 0-15, 0-30 or 0-150 lumens per square foot), the required range being selected by a rotary switch. The microammeter used has been specially developed to provide a highly sensitive movement of the robust nature most suitable for a portable instrument. Four cells are connected in parallel in the photocell unit so that high sensitivity is achieved and at the same time sufficient output is provided to operate the microammeter. The instrument is

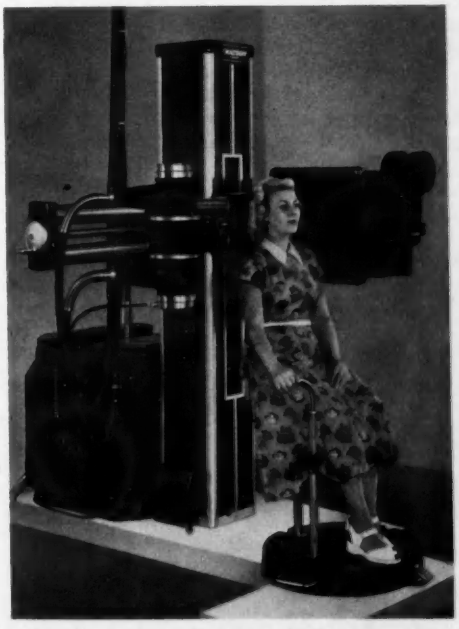


Fig. 64.—Cine-radiography equipment with a patient in position on the rotatable platform. The Super Dynamax rotating anode tube is in the foreground and the camera unit on the patient's left.

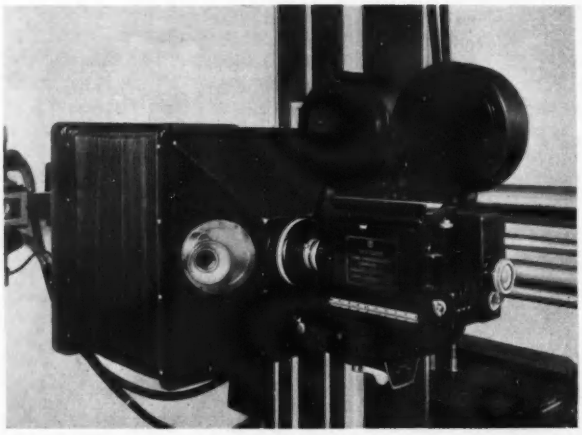


Fig. 65.—The camera unit showing the self-closing inspection port for the visual examination of the image on the fluorescent screen.

equipped with a level, a boss for attachment to a camera tripod, and a sighting device that enables the unit to be placed normal to any particular source of illumination. To obtain the best possible cosine response, the cells are covered with a special coating, no other protection being used.

Whenever a new frequency range is used for radio communication work, one of the first requirements is apparatus for accurate measurement of impedance. The familiar twin-T circuit has been widely used for measuring impedance at low frequencies, but it has now been adapted for use at frequencies of several hundred megacycles per second. One instrument incorporating a twin-T bridge has recently been developed for use in the frequency range around 300 Mc/s, and measures impedances of the order of 75 ohms. The actual impedance is given in terms of a parallel capacitance and conductance, and an unusual feature of the instrument is that both the conductance scale and the capacitance scale are independent of the frequency at which measurements are being made.

The radio altimeter, developed in co-operation with the Royal Aircraft Establishment, Farnborough, from the Establishment's original design, represents a modern application of a technique used in wartime radar. The altimeter is designed to give the pilot of an aircraft an accurate indication of actual ground clearance, and thus provides for greater safety in flight. In this instrument, high frequency energy in the form of a continuous wave is transmitted towards the ground, where it is reflected back to the aircraft. The frequency of the transmitted signal is varied with time, increasing or decreasing between the limits set by 1,605 Mc/s, and 1,655 Mc/s. The frequency of the received signal will, at any one instant, be different from the transmitter by an amount depending on the time delay suffered by the returned wave. This, in turn, is proportional to the distance between the aircraft and

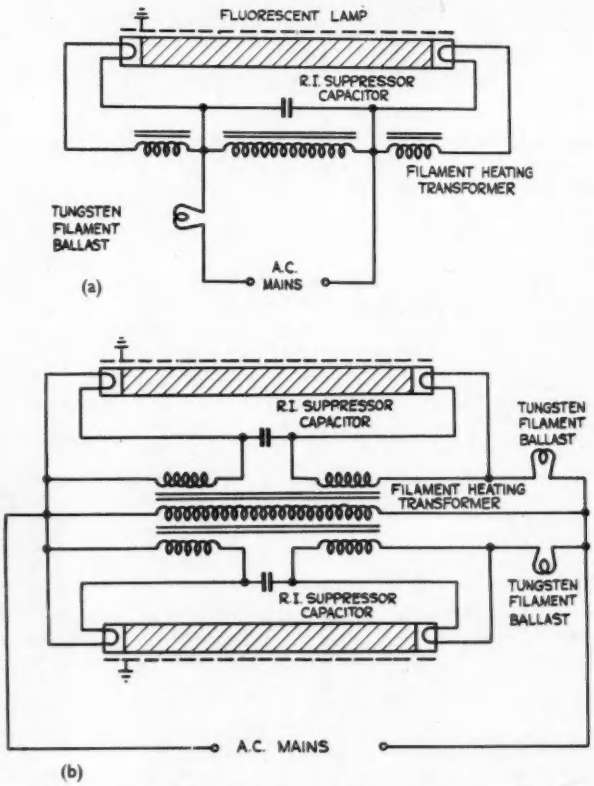


Fig. 66.—(a) Single lamp circuit using tungsten filament ballast. (b) Double lamp circuit using tungsten filament ballast.

the ground. The difference between the frequencies of the transmitted and received signals leads to the production of beats, whose mean frequency gives a direct measure of the height of the aircraft. The altimeter gives reliable indications of height up to 5,000 ft. over all types of terrain, including dry desert, which reflects only 3 per cent of the incident high frequency energy.

An instrument of great potential value in the medical field has recently been produced (figs. 64 and 65). This apparatus makes it possible to record, without injury to the patient, a continuously moving X-ray picture as seen on a fluorescent screen. Such equipment greatly increases the scope and usefulness of X-ray methods in diagnosis. While this idea is not new, it is only recently that the great advances in X-ray tube design, fluorescent materials, fine-grain film, and cinematographic equipment generally, have enabled such an apparatus to be made suitable for routine hospital use. The Watson cine-radiography equipment incorporates the new Machlett Super Dynamax rotating anode X-ray tube, in a generator capable of developing 120 kV at 400 mA. The specially designed 35 mm. cine-camera used has an f. 0·7 Taylor Hobson lens of 4 cms. focal length. Both the exposure of the patient to X-radiation, and the loading of the X-ray tube, are kept to a minimum by the use of an electronic contactor, so arranged that the X-ray tube and generator are energised only while the shutter of the camera is open. Frame speeds are adjustable from about $3\frac{1}{2}$ to 50 frames per second in sub-multiples of the mains frequency. The equipment is so designed that the X-ray beam can be diverted at any angle and used either above or below a table supporting the patient. A separate control panel allows for the remote control of all the operations when once the camera has been focused and the beam diameter correctly adjusted. The more usual still radiography can also be carried out with this equipment.

LAMPS AND ILLUMINATION.

The use of fluorescent lighting, particularly in the home, is often restricted by the relatively high initial cost. In the circuits shown in fig. 66 (a) and (b), a filament lamp is used as ballast, in place of the more costly choke, to control the fluorescent lamp current. A small auxiliary transformer heats the lamp filaments during starting and running as in the " instant start " arrangements. Fig. 67 shows a fitting designed to make the most efficient use of the light both from the fluorescent tubes and filament lamps used as ballast. This fitting uses two 4 ft. 40 watt lamps, whose light is diffused by a white or tinted medium, with two filament lamps which are shielded by the spine of the fitting to give only direct light. A very good blending of light is thus obtained with an attractive red component.

Improvement in the colour-rendering properties of fluorescent lamps by adding light from incandescent lamps, is, of course, widely practised in commerce and industry. There are, nevertheless, many circumstances in which this is not the desired solution, and work to improve the colour-rendering qualities of fluorescent lamps continues.

The now well-established " Mellow " colour was introduced early in the past year. Practical experience with this colour has amply justified the extensive laboratory and field trials mentioned in last year's review of progress, undertaken in the search for a warm colour suitable for " social " lighting. A " colour matching " lamp is also available and may be used for all but the most exacting colour matching requirements.

Interest in fluorescent lamps does not rest solely in the " white " range of tubes, and a set of four coloured 5 ft. 80 watt lamps recently introduced will be valuable for decorative work and possibly for stage lighting. The colours

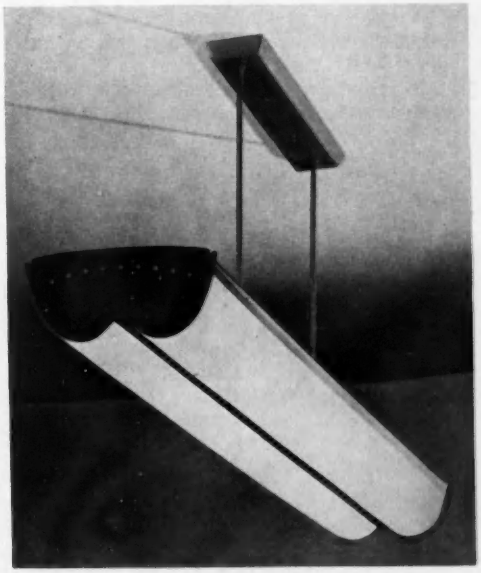


Fig. 67.—Domestic pendant fitting for two 40 watt fluorescent lamps with two incandescent lamps.

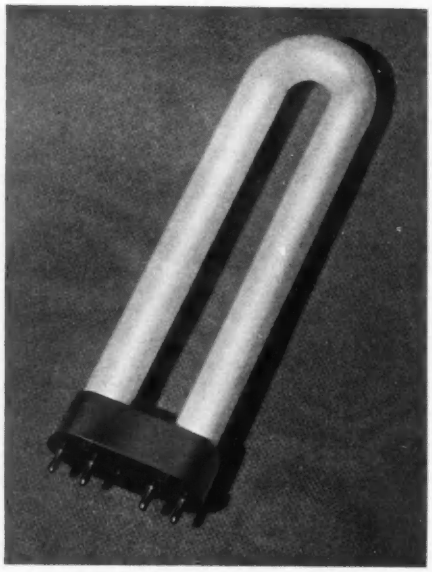


Fig. 68.—8 watt fluorescent lamp.

chosen are red, yellow, green and blue, and the aim has been to develop these in saturated rather than pastel shades. The blue and green lamps have their phosphors coated in the normal manner on to clear glass. The red and yellow colours are obtained by first coating the clear glass with a layer of pigment, the optical properties of which are carefully controlled, and this is subsequently covered with the normal layer of fluorescent material. The luminous efficiencies of the red and blue tubes are low in comparison with those for the yellow and green tubes owing to the much lower visual sensitivity of the eye at the ends of the visible spectrum. Nevertheless, the actual efficiencies of all four colours are higher than can be obtained by a tungsten filament lamp combined with a filter, as can be seen in the third column of the table.

Illuminating engineers are much interested in forms of the fluorescent lamp other than the familiar straight tube. Although many different shapes can be produced by hand-bending, considerable difficulties are involved in mechanising the bending operations. Encouraging progress has now been made with a semi-automatic machine, and a U-shaped 8 watt lamp (fig. 68) is now being made experimentally. This is for use in train berth lighting where a small source is required with a good light output but little heating effect.

Attention is being given to the problem of dispensing with the bulbous electrode housing in cold cathode lamps without altering their performance or electrical characteristics. Tubes having a uniform diameter throughout will be more easily handled and transported.

INITIAL EFFICIENCY OF COLOURED TUBULAR FLUORESCENT LAMPS.

Colour	Initial Efficiency for 5 ft. 80 watt lamps	Approx. efficiency of filament lamp and filter combination of similar colour
Red	4 lumens/watt	2 lumens/watt
Yellow	30 lumens/watt	8 lumens/watt
Green	50 lumens/watt	4 lumens/watt
Blue	13 lumens/watt	2 lumens/watt

The ability of electric discharges to generate radio frequency oscillations in certain circumstances is well known. Measurements show that discharge tubes used for lighting purposes generate only very small amounts of radio frequency energy and, when properly installed, the great majority of such lamps do not give rise to interference with broadcast reception.

Fig. 69.—The main lounge of the M.V. "Oslofjord" illuminated by cold cathode and tungsten lighting.

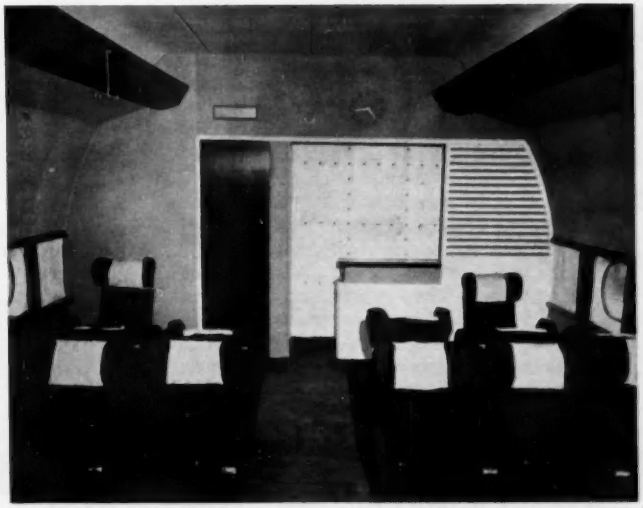
Fig. 70.—Control room at Northolt Airport.

The most interesting lighting installation completed during the year is that for the new House of Commons, which is the subject of the first article in this issue.

Although at the time of writing none of the lighting installations for the 1951 Festival of Britain Exhibition is yet completed, much exploratory work has been undertaken. The Royal Festival Hall, which will remain as a permanent concert hall, is being lit by a large number of the recently introduced 150 watt reflector spot lamps inset in the ceiling. The ceiling itself is lighted by cold cathode tubes concealed in nine alcoves spanning the width of the hall, each alcove containing a triple line of tubes in eleven sections each 8 ft. 6 ins. long. A similar, but somewhat smaller, installation provides light beneath the gallery. Dimming control is effected by operating each group of six or seven tubes from a tandem pair of step-up transformers, the primaries of which are controlled by a variable series resistance. These resistances are suitably ganged to provide ease of control. Smooth dimming in the ratio of 700 to 1 has been achieved by careful attention to the circuit design.

Many of the problems connected with the lighting of collieries have already been overcome, but much remains to be done. Experiments, using fluorescent, mercury discharge, and filament lamps, are being carried out in conjunction with the National Coal Board. Economic considerations have led to a revival of interest in the filament lamp, and this light source has been incorporated in a new flame-proof unit for lighting the coalface. This unit is provided with a diffusing cover which materially reduces glare. Although full-scale trials are constantly being carried out in the collieries, such trials are costly and relatively laborious. A half-scale laboratory model is therefore being used for the experimental work now in progress on mine roadway lighting.

Another interesting investigation has been concerned with the lighting of airport control rooms, and this type of lighting has also been studied in a laboratory model as well as on site. The problem was to provide sufficient light to illuminate the control desk, without destroying the Control Officer's dark adaptation, and at the same time to avoid reflections in the windows of the control room, so that objects on the aero-



[By courtesy of The Bristol Aeroplane Co., Ltd.

Fig. 71.—Fluorescent lighting in the saloon of the Brabazon I.

drome could be seen. The unit evolved uses two " Striplites " in conjunction with a system of louvres, and the illumination may be dimmed by the Control Officer. Prototypes have been in service both at London and Northolt Airports (fig. 70).

Although fluorescent lighting is now firmly established for all forms of transport, each mode of travel presents its own problems and every installation must be designed to meet particular requirements. Sometimes, and especially in the air, it is an advantage to operate the lighting from relatively high frequency A.C. supplies. For example, the saloon and bar of the Brabazon Mk I aircraft is lighted by 20 watt fluorescent lamps operated on a 400 cycle supply derived from inverters. The lighting is indirect, the lamps being housed in troughs (fig. 71), and special lightweight control gear is used.

The London Transport Executive's programme for new and re-equipped stock includes the installation of fluorescent lighting, and large numbers of 2 ft. lamps with their associated control gear for 850 cycle operation have been supplied. Some trains on District lines are now operating with fluorescent lighting, twenty-four 20 watt lamps being used in each saloon-type coach.

In contrast, a trolley bus has been equipped with 15 in. 14 watt fluorescent lamps supplied direct from the vehicle battery at 60 volts, so that no special inverter is required.

New systems of lighting, and the successful use of new lamps, depend ultimately upon the design of new lighting fittings and equipment. The requirements for such equipment are becoming continuously more stringent and harder to satisfy, so that designers are always looking out for better materials and methods of manufacture.

Fig. 72.—Roundabout lighting at Reading with 250 watt mercury vapour lamps in Blown Glass Cut-off lanterns

For example, the improvement in street lighting during the past few years has been brought about by the use of lanterns giving a carefully controlled optical performance. This was possible only by designing lanterns with more critical optical systems. Great care is required to maintain the quality of the glassware used for reflectors, as well as the dimensional accuracy of the component parts which contribute towards the final performance of a lantern in the street. Considerable work has been carried out during the last year to assist and ensure the production of components having a standard that will enable each lantern to fulfil its required function.

To help aircraft to land in conditions of very bad visibility aerodrome runway lights of greater intensity are needed and this has given rise to several new problems. Thus, the particular requirement that all " flush-mounted " lighting fittings should be watertight under all conditions can be met only by the use of special seals able

to withstand the high temperature resulting from the use of larger lamps. Because of the restriction on the size of the " flush-mounted " light, and its unsuitability for use in countries where snow is common, high intensity lights, standing 2 or 3 feet above the ground, are now being supplied. By reason of the obstruction they would offer to aircraft, these lights must be mounted at the edge of the runway and thus the distance between the two rows of lights becomes greater. This, in turn has led to the demand for a unit giving a wide beam of high intensity. Fortunately this result can be more easily obtained with elevated lights whose size is less restricted than that of the " flush-mounted " type. One such elevated unit uses a 100 watt projector lamp and gives a beam both up and down the runway with a maximum intensity of 40,000 candelas and a beam width of 16°.

It is important that an incoming pilot should know the height of clear air between the ground and the underside of the clouds over the airport. This height is measured with the aid of a ceiling height or cloud base projector (fig. 73) which projects a patch of light on to the cloud : the angular elevation of this patch is determined at a fixed point at a known distance from the projector and the cloud height computed.

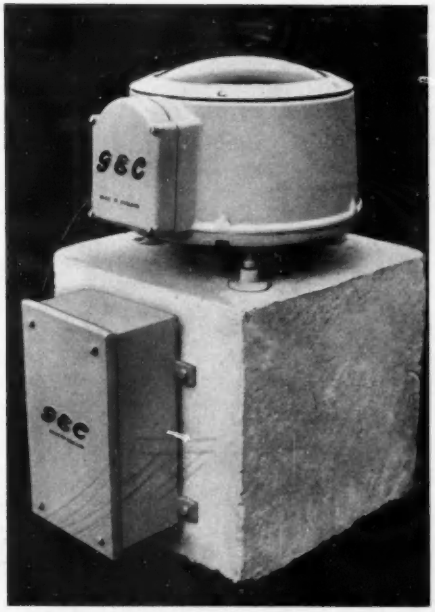


Fig. 73.—Ceiling height projector used for visual determination of height of cloud base.

A new type of dust-tight reflector for fluorescent lamps has been produced. This avoids a cumbersome gasket joint between the reflector and glazed cover by arranging only for end-access to the interior, which can be withdrawn for maintenance. The glazing is thus permanent which allows a better seal to be made.

Fig. 74—2½ kW xenon compact source lamp.

Another exacting situation for a lighting fitting is under water. The return of decorative lighting has revived the demand for watertight floodlights suitable for lighting fountains, and the like. The " diving bell " principle has been applied to a new range of floodlights which has many advantages over previous designs, notably the avoidance of any watertight joints or glands. One very compact unit uses the 150 watt reflector spotlight lamp. Other sizes range from a 60 watt unit for small pools to the 500 watt floodlight for large fountains.

The following are examples of fittings designed to use new or special lamps. One, suitable for high bay lighting, uses to advantage the

high light output (56,000 lumens) of ten 1 kW high-pressure mercury vapour lamps while providing adequate cooling. The reflector, of anodised aluminium, has a ventilated canopy, and is designed to give a concentrated light. A wire mesh guard is fitted over the mouth of the reflector. Sixty of these units have been installed in the new turbo-generator shop at the Witton Engineering Works.

New fittings designed for use with germicidal lamps have been tested, and are being used for sterilising air in rooms and for other medical applications.

The design of fittings that house ballast and control gear for discharge lamps is obviously affected by the shape of this ancillary gear, and a major modification has been made in the design of the fitting for 80 watt fluorescent lamps. The chokes so far available have been of two types : the original cubic design which had low loss but was cumbersome in shape, and the long design of a convenient, slim shape but with a high loss. In the new " brick " choke, a design has been established which is convenient, economical in material and has relatively low loss. Its features have been described in some detail in the October, 1950, issue of this Journal. The new shape makes it practicable to build both the choke and the starting transformer into one composite instant-start control unit. Units of this type are now available, and provide for the first time instant-start gear which permits the lamp to give its full rated light output on all supply voltages.

Standard dimming gear, capable of providing smooth dimming down to about 10 per cent of full light output, is now available for 5 ft. lamps. This dimming range is adequate for all normal purposes.

Work continues on high intensity sources, and a new type of compact source lamp that provides light of a colour closely resembling sunlight is being developed. Its form is similar to that of the Osram 2½ kW compact source lamp, but the mercury-cadmium filling is replaced by the rare gas, xenon, at a pressure of about one atmosphere. Such lamps have been made experimentally for A.C. or D.C. operation at 2½ and 5 kW. Fig. 74 shows a xenon lamp designed for D.C. operation at 2½ kW. The luminous efficiency is about two-thirds and the luminance about one-third of that for mercury-cadmium lamps at comparable wattage loading. Owing to their high pressure gas filling these lamps, unlike mercury vapour lamps, attain full light output immediately after starting and may be restarted for immediate use at any time after extinction. The starting circuits are similar to those employed in the " Compact " floodlight used in motion picture studios.

The latest installation of 2½ kW mercury-cadmium compact source lamps in television studios is in Denmark, where the Danish Broadcasting Corporation uses " Softlight " units in the Copenhagen studios. The advantages of continuous operation, silence, and coolness are, of course, very suitable for this purpose.

Discharge lamps are now competing with the carbon arc as sources of illumination in photographic printing processes. The light output of the discharge lamp used is comparable with that of the carbon arc, and it has the advantage that it is clean and requires no adjustment. A special printing floodlight has been designed which incorporates the stand-by, simmering arrangements used in the compact studio floodlight described in the October, 1948, issue of this Journal. The remotely controlled shutter assembly is identical with that used in the studio floodlight, the reflectors being hinged so that they are brought round the lamp to form the simmering enclosure. The fitting is, however, suspended so

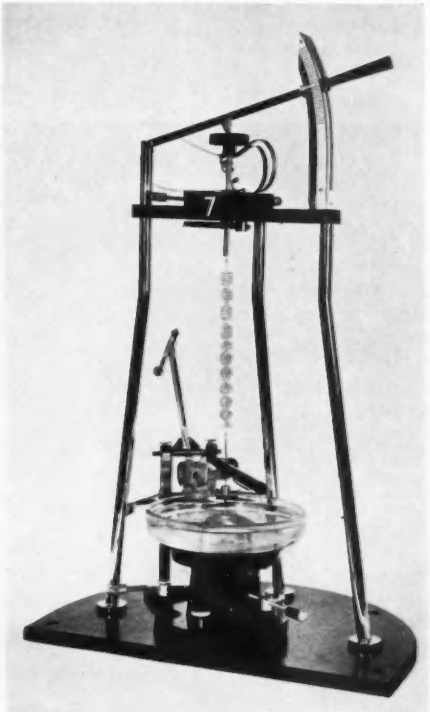


Fig. 75.—Production unit for diamond die piercing by electric arc.

that the lamp operates horizontally and the light is projected downwards. The same control gear is used as in the floodlight, and is mounted separately. A Chamberlain and Hookham process timer has been included : any exposure between 0 and 100 seconds can be repeated

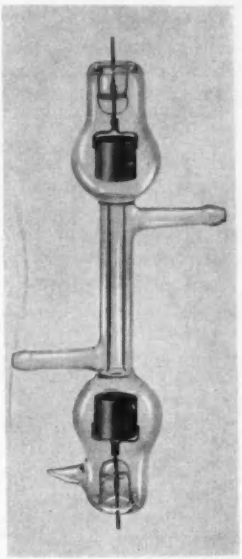


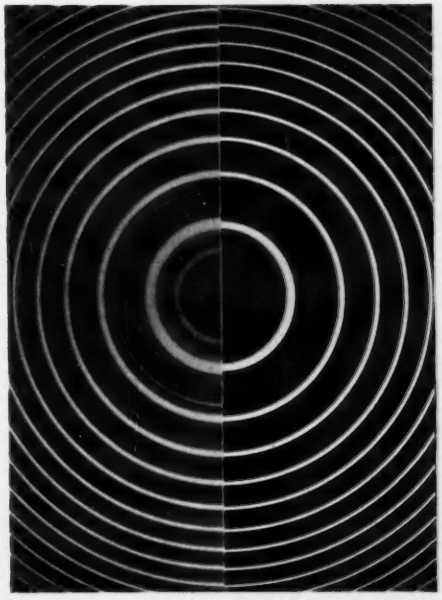
Fig. 76.—Mercury isotope discharge lamp, water-cooled type.

indefinitely to within close limits. This equipment has proved very successful in service, the exposure times required being appreciably shorter than those needed for earlier forms of equipment.

There has for a long time existed in the photographic world the need for a primary battery of the same size as the standard torch unit cell, but capable of giving the much higher current required to operate the modern photographic flashgun. The standard torch unit cell is designed to give a current of about 0·3 amperes for protracted periods, whereas a modern photographic flashgun requires momentary currents of 5 to 7½ amperes, for both the flashbulb and the solenoid which operates the camera shutter. The maximum duration of the load is usually one second, and this may recur rapidly while a series of photographs is being taken or at extremely long intervals. The BA.6115 Photoflash cell has been designed for flashgun use and will give an initial short-circuit current of 10 amperes. The metal cap which seals the top gives added security against corrosion and greater rigidity. These cells can be used with two new photographic bulbs now on the market, the " Speed-Midget " and the " No. 5 ", which have luminous outputs of 4,500 and 16,000 lumen-seconds respectively. The " Speed Midget " bulb, in particular, has been designed for the amateur photographer.

Another tool developed for photographers is the Photogrid. This is a " tailor-made " cold cathode light source formed from 15 mm. or 20 mm. fluorescent tubing, bent into a grid or helical square. Photogrids have various applications where a diffuse source of 10 ins. to 15 ins. square is required, and are particularly useful in photographic enlargers.

Despite the increasing number of developments in discharge lamps, the tungsten lamp is still the most widely used of all light sources. The developments in this field are therefore of great importance. Over a period of many years much effort has been expended on the production of a lamp with an adequately diffusing bulb, but one of the chief difficulties has been the inherent absorption of the diffusing media. The pearl lamp, which was introduced in 1925, combined reasonable diffusion with low absorption, and was widely adopted. The recently intro-



[By courtesy of the National Physical Laboratory

Fig. 77.—Composite Fabry-Perot interferogram in natural mercury and 198 isotope, green radiations.

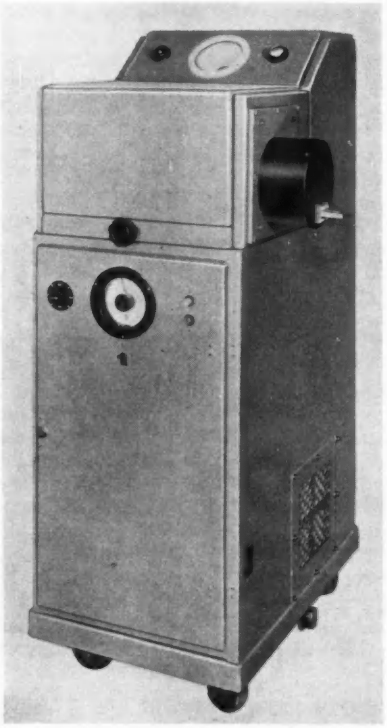


Fig. 78.—2 kW H.F. induction heating set for soldering, brazing and hardening applications.

duced " Silverlight " lamp, in which the inside surface of a pearl bulb is coated with very finely divided silica, gives greatly increased diffusion with low light absorption. This new lamp is now available in the 100 watt rating.

Both clear and inside coloured 15 watt sign lamps, for decorative purposes, are again being manufactured. These lamps, which were made before the war, are now coloured by means of a process similar to that used for coating fluorescent tubes, with very uniform results.

Essential to the production of tungsten wire, and hence to most types of incandescent and discharge lamps, are the diamond dies used for wire-drawing. Recent work has resulted in a great saving of time in the rate of piercing diamonds by using an electric arc in place of the more normal method of cutting with finely powdered diamond. A saving of a hundred hours or more has been achieved, and, in general, the finer the bore required the greater is the time saved. The electric arc technique is not yet used for the whole process of making the die. It is first necessary to make a conically-shaped incision into the stone by using diamond powder, and after this the new technique can be applied. The stone is held just beneath the surface of a suitable electrolyte and a pointed platinum alloy needle inserted into the cone. The circuit is completed by a second electrode in the solution and, with suitable electrical controls, arc voltages down to 40 volts can be used. Holes as small as 0·0002 in. diameter have been produced in diamonds with an electric spark and it is very doubtful if holes of this dimension have ever been produced by cutting away with diamond powder. A photograph of a modern production unit is shown in fig. 75.

In last year's Progress article, brief reference was made to special mercury isotope discharge lamps for laboratory use. Considerable experience has now been obtained in the application of these lamps, using both air- and water-cooling. The water-cooled lamp shown in fig. 76 has a life of about 250 hours at an operating current of 25 milliamperes.

The effect of using isotope lamps as new sources for interferometry is clearly illustrated in fig. 77 (reproduced by courtesy of the Director of the National Physical Laboratory). The left-hand half of the circular fringe pattern was produced with green 5461Å radiation of natural mercury

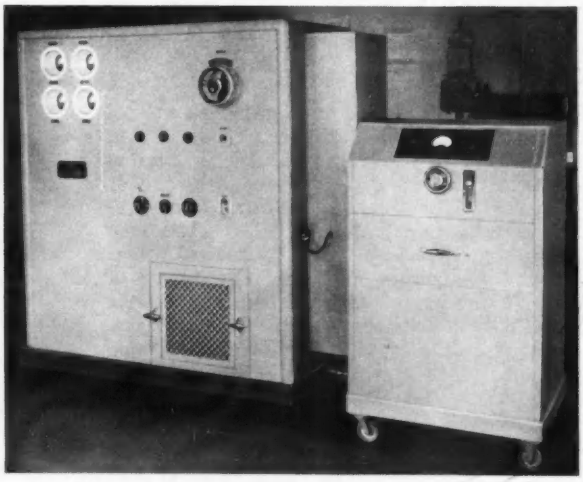


Fig. 79.—5 kW dielectric heating set with preheating oven.

and the components due to the various isotopes are clearly distinguishable. Radiation of the same frequency produced by a lamp containing the single mercury isotope 198 lamp was used to obtain the right-hand half of the pattern, which is a system of well-defined lines. The water-cooled lamp has already proved very useful as a source for interferometry over large path differences. End standards up to six inches in length have been measured directly, this upper figure corresponding to an order of interference of approximately 550,000. It is also possible that the lamp may have applications in the definition of standards of length.

INDUSTRIAL AND PROCESS HEATING.

The increasing use of high frequency heating for industrial purposes has fostered continual improvement in the design of the electrical equipment. Much of the standard equipment was described last year ; more recent refinements are embodied in the 2 kW set (fig. 78) now in service for soldering, brazing and hardening ; the 5 kW dielectric heating set with preheating oven (fig. 79) which is of particular value to the rubber industry ; and the 5 kW high frequency induction heating set with rocker pad hardening machine (fig. 80).

A new shop has been brought into operation at the Witton Works for the manufacture of vacuum capacitors (fig. 81) for high frequency service ; a particular application is their use in connection with high frequency heating equipment. These capacitors are produced in a standard range of capacities from 50 $\mu\mu F$ up to 300 $\mu\mu F$ and for working voltages up to 12 kV.

A new plant recently installed for bright annealing brass and copper tubes (fig. 82) comprises a 300 kW resistance furnace connected with a three-position cooling chamber having externally controlled traversing gear. External loading and unloading platforms are provided. This equipment can handle tubes up to 30 ft. long in 6-ton batches by a continuous process in which the charge is purged, brought up to the annealing temperature, and force-cooled before being withdrawn on to the unloading platform. The furnace temperature is automatically controlled and the movement of the charge fully mechanised. The controlled atmosphere for the furnace and cooling chamber is supplied by two gas burners, using 1,000 cubic feet of propane an hour.

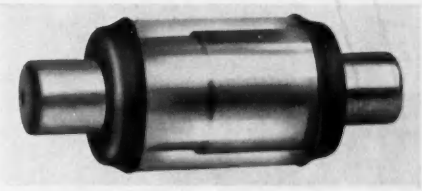


Fig. 81.—280 picafarad 11 kV vacuum capacitor.

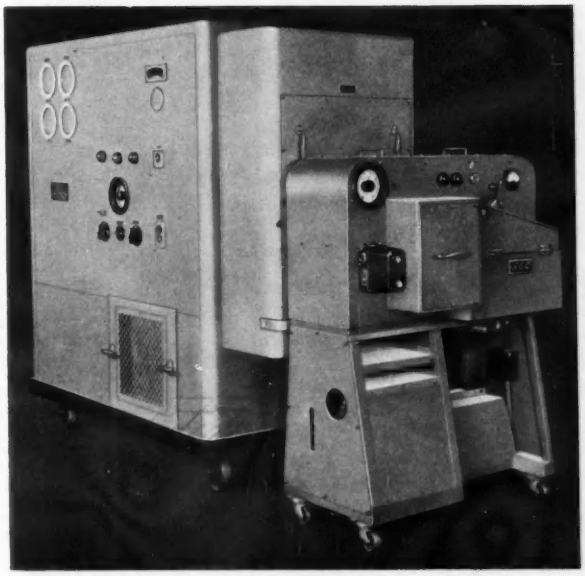


Fig. 80.—5 kW. H.F. induction-heating set with rocker-pad hardening machine.

The number of processes using controlled atmospheres for metallurgical operations is increasing. The present range of such processes includes bright brazing, hardening, normalising and annealing, gas carburising, gas malleablising, and more recently, carbonitriding. The last-named process produces a hard case on steel by introducing carbon and nitrogen from a gas atmosphere into the surface of the steel at a temperature between 800 and 875 degs. C. The steel is then cooled at the rate required to give the desired properties. Complete installation and technical data can now be offered with the equipment for this process. The case produced by carbonitriding is similar to that produced by liquid cyaniding, but the new process is cheaper, eliminates the cyanide waste, and permits the control of case

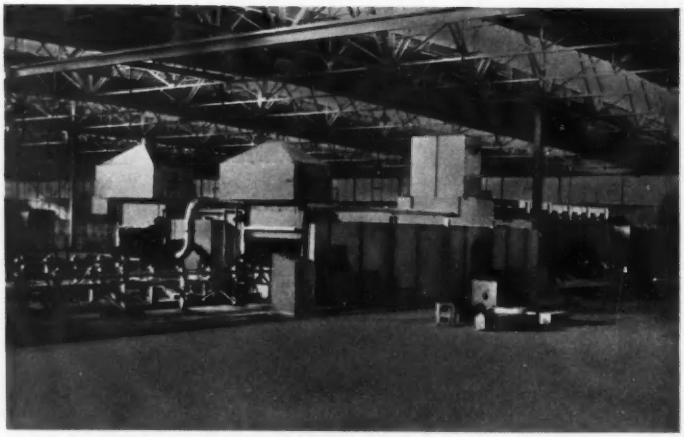


Fig. 82.—300 kW resistance furnace for bright annealing brass and copper tubes.

composition as well as its depth. It has, too, several advantages over the gas carburising process, since the lower treatment temperature results in greater wear resistance of the case and less distortion of the steel. The use of nitrogen increases the ease of hardening of the case and thus may permit the use of plain carbon steels in place of alloy steels.

Gases of controlled composition are now so widely used in industry that it has been necessary to develop a range of generators of such controlled atmospheres. Fig. 83 shows a town gas burner, with a desulphuriser, for producing 1,000 cubic feet an hour of an atmosphere suitable for many heat treatment processes. This town gas burner is, for instance, used with the furnace shown in fig. 84, which is employed for the bright brazing of refrigerator components.

The plant shown in fig. 85 produces an atmosphere that is used for the heat treatment of carbon steels. The installation comprises an electric furnace with automatic temperature control gear and a heat resisting steel retort containing a catalyst over which a mixture of air and town gas is blown. The plant illustrated will produce 2,000 cubic feet of atmosphere an hour.

Two new items of equipment have appeared in the radiant heating field. One is a trough having a light cast and sheet metal framework, which carries two sheathed wire elements, backed by a reflector (fig. 86). These troughs are 3 ft. long by $10\frac{3}{4}$ ins. wide, and have a maximum electrical loading of 3 kW. The intensity of the radiation produced is slightly higher (1·1 compared with 1·0 kW/sq. ft.) than that from a unit of the same size using internal reflector lamps. Unit troughs of this type can readily be joined together to make a heating plant. If required, only one of the two elements may be used, or the two may be run in series, so that a half or a quarter respectively of the maximum loading may be used. The sheathed wire element is a much lower temperature source than a lamp filament, and the longer wavelength radiation emitted ensures that the rate of heating of an article is less dependent on its colour than when lamps are used.

A paint repair unit has recently been introduced. This is designed to provide local heating to accelerate the drying of paint in retouching damaged paint work, particularly on car bodies (fig. 87). The heat is supplied by 115 volt, 250 watt internal reflector lamps. The unit, which can house either two or four lamps, is mounted at the end of an adjustable metal arm connected by a clamping device to a tubular metal stand on rubber-tyred castors. The lamps can thus be readily adjusted to irradiate any part of a car body. A connection for a compressed air supply is provided so that the lamp housing can be kept

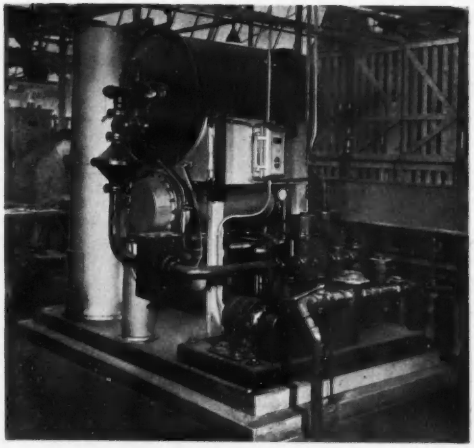


Fig. 83.—Town gas burner with desulphuriser ; nominal output 1,000 cu. ft. an hour.

at a positive pressure and free from any inflammable solvents. This feature has the approval of H.M. Inspectorate of Factories.

A technique that uses radiant heating to accelerate the drying of wood finishes has been developed, and is proving of great interest to the furniture trade. Most furniture is finished with cellulose lacquer, a typical process consisting of filling, sanding, staining, applying two coats of lacquer and "pulling over". The practice hitherto has been to allow these coats to air-dry, the total time from white wood to packing being at least 18 hours and often considerably longer. When the new radiant heating method is used, the whole series of processes can be completed in less than three hours. The new technique also permits a considerable reduction in the floor area allocated to drying, and enables furniture finishing to be completed on a conveyor line with consequent economy in labour costs and avoidance of damage through handling. Both cellulose and synthetic finishes are being dried satisfactorily in times of about five minutes. Most common veneers, including oak, walnut, mahogany, maple, sycamore and teak, can be finished and force-dried successfully without blistering of the finish or distortion of the veneer.

The increasing availability of electricity in the East has led to a demand for an efficient method of cooking rice, the staple food in many of these countries. After considerable research into the various methods in vogue, an appliance has been developed which satisfactorily meets all requirements. The rice cooker, which is seen in fig. 88, consists of a monel metal container, of approximately 20 gallons capacity, with a perforated bottom which fits into a lagged outer case having a hinged lid. A steam generator

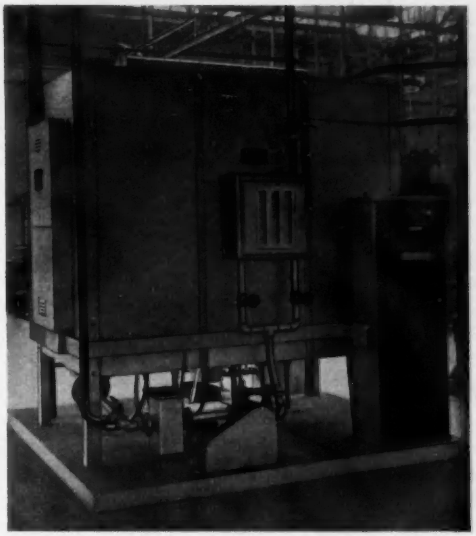


Fig. 85.—Air-gas reactor with an output of 2,000 cu. ft. an hour.

Fig. 84.—Moving belt furnace for brazing refrigerator components. The controlled atmosphere keeps the parts clean and no flux is necessary.

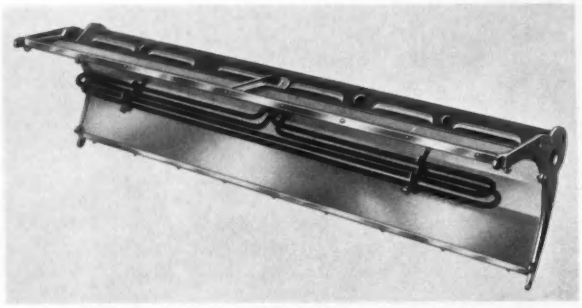


Fig. 86.—Sheathed wire element trough for radiant heating applications.

of 9 kW loading, and with an automatic water feed, is housed in the bottom of the case. Particular care has been taken to provide facilities for washing through after use. The cooker will take some 100 lbs. of dry rice which, after washing and soaking, is tipped into the inner container and the steaming begun. Dependent on the type of rice used the cooked rice can be removed in $1\frac{3}{4}$ to 2 hours. Care has been taken to allow for the traditional and necessary addition of cold water and frequent stirring.

It might appear from the illustration that the cooker is unduly low, but the height has been carefully determined as being the most convenient for use in the countries for which it is intended since the average individual in the East is shorter than in Europe.

A steaming oven has been developed so as to provide kitchens with a steam cooking oven with all its attendant culinary advantages but without the serious disadvantage of costly steam generating plant. The latest design of oven comprises a tinned copper interior, fitted with baskets, and a steam tight door. A vent is provided which serves the double purpose of an outside condensate drain and an open exhaust to the air, thus preventing any pressure developing. The steam generator, rated at 9 kW, is mounted in the bottom together with the automatic water feed. Switching is effected by means of an indicating control unit with the option of thermostatic control mounted on the side of the oven.

An installation of four ovens of this type has been made in the canteen of the Brunswick Wharf power station of the B.E.A., London (fig. 89). They form an important part of the equipment, being used for the steam cooking of puddings, vegetables and fish. The

Fig. 87.—Infra-red paint repair unit.

Fig. 88.—Electric rice cooker for use in the East, embodying a 9 kW steam generator.

remainder of the cooking equipment in the canteen was also supplied by the G.E.C.

AGRICULTURAL AND DOMESTIC HEATING.

There continues to be a marked interest in electrical equipment for agricultural and horticultural uses. To meet the needs of modern farming methods the range of equipment for such applications as dairy sterilising has to be continuously supplemented. The heat storage system that allows use of a low and distributed electrical load is now incorporated in a 1 kW storage block steam raiser. This unit provides steam and hot water simultaneously, with automatic control of operation. Primarily designed for use on dairy farms, it will provide sufficient steam for a lagged sterilising chest up to 27 cu. ft. capacity and three or four milking clusters or churns. If conditions are not too severe, it may be used with a two-unit recorder milking plant or for steel utensils in an unlagged 27 cu. ft. chest. The water heater has a capacity of 20 gallons which, when diluted with cold water, will provide 25 to 35 gallons of hot water for washing-up, udder washing and so forth. The electrical loading is 1 kW for the block and 1 kW for the water heater. If hot water is required only in the afternoon, the maximum day load need not exceed 1 kW and operation can be arranged at off-peak times.

A separate 20 gallon water heater is now also available to the smaller farm dairies and ice cream establishments.

Fig. 90.—Heated food container for use in aircraft.

The value of sterilised soil is becoming more widely acknowledged, with an increasing appreciation of its contribution to the growth of healthy plants, by the destruction of pests and disease in the soil. Sterilisation is effected by raising the soil to 180 degs. F., at which temperature harmful organisms and weeds are destroyed without affecting those properties of the soil that are essential for sturdy growth. A new soil steriliser has recently been introduced which is very simple to use and is made in a size convenient for the average grower ; if desired, several units can be used to extend the capacity of the installation. The plate-type resistance heaters, which form a special feature of this design, ensure uniform distribution of heat throughout the soil. An important advantage of this type of heater is that the current is confined to an embedded sheathed wire element ; as the heating effect does not depend on current flowing through the soil, the electrical

Fig. 89.—Electric steaming ovens at Brunswick Wharf power station, London.

loading is constant at all times, and does not vary with the composition or moisture content. This means that special experience or skill is not required in preparing the soil. The fact that steam is not injected into the soil during sterilising contributes to simple and clean operation and the soil is friable and easy to handle immediately it leaves the sterliser.

In the field of domestic heating appliances, a boiling plate controller known as the " simmer switch " has been introduced to give continuously variable control over the heating rate of boiling plates on domestic electric cookers. This will enable the user to select the appropriate rate of heating for any particular cooking operation, and to have much greater control over boiling or simmering. The controlling switch has an indicating scale which is especially open over the simmering range. The rating of the controller switch is 10 amperes at 250 volts and the operation of the unit is independent of ambient temperature.

Another development, hardly a domestic appliance, but likely to help in improving the amenities offered to travellers by air, is a new heated food container (fig. 90). These compact and light boxes will hold $1\frac{1}{2}$ gallons of liquid or 12 plates of food and will replace the heavy vacuum flasks now in service. Hot liquid or food is placed in the container and the temperature is maintained by four 28 volt, 50 watt sheathed wire heating elements. The inner case is of 22 gauge Monel metal and the outer 20 gauge BA/60 aluminium alloy. " Fibreglass " is used as lagging between the two, and the top plate is a " Bakelite " moulding with spring clip fastening and a handle which folds flat. This new container is to be used by British European Airways on their services using Dakotas, Ambassadors and Viscounts.

WELDING EQUIPMENT.

Many orders for A.C. welding equipment have been received for home and overseas use, one of the larger export orders being for thirty-four single operator portable sets for service on the railways in China.

Attention has previously been directed to the advantages of twin-arc welding.[1] Over the past twelve months several prototypes of a twin-arc portable welding unit have been in experimental service in the Company's works and at Imperial Chemical Industries and Welding Rods, Ltd. The results obtained have fully justified the claims made for this equipment which has therefore been brought into regular production. These sets are suitable for service on 3 phase, 360/440 volt supplies, and are so designed that they can also be used as normal double operator sets, if desired.

The electrical advantages, particularly that of improved power factor, are apparent from the data given in the table. Two simultaneous welds, each 12 ins. in length and approximately equal in cross-section, were made by two operators, one using a 4 S.W.G. electrode running at its maximum current from a normal single-phase supply and the other using twin 6 S.W.G. electrodes of the same type supplied from a twin-arc set.

	Fillet size $\frac{5}{16}$ ins. approx.	
	Single Arc.	**Twin Arc.**
Electrode size ...	4 S.W.G.	two 6 S.W.G.
Time for 12-inch weld	98 secs.	70 secs.
Primary voltage ...	405	405
Primary current amps.	65, 65, 0.	32, 32, 34.
Primary kW ...	9·7	12·8
Primary kVA ...	26·3	23·0
Power Factor ...	0.38	0·56
Welding Current amps.	315	215, 220
Arc Voltage	23	25
Secondary Voltage ...	80	45
Striking Voltage ...	80	35

NOTE.

Certain discrepancies in the above figures are due to the fluctuation of the meters under welding conditions.

In the early experimental work on twin-arc welding technique the electrode holders incorporated a manually-operated switch for the purpose of extinguishing the arc across the electrode tips when withdrawn from the workpiece. The difficulties in production of the holder arising from this feature were very considerable, and, as a result, an alternative method of arc extinction was developed. This is now effected by a compact automatic relay-operated contactor which opens as soon as the electrodes are withdrawn by an inch or more. This has enabled the holder to be designed as a light but extremely robust tool capable of standing up to the roughest workshop use.

[1] " New Developments in Design and Operation of A.C. Welding Plant," by E. C. DAVIES, A.M.I.E.E., *G.E.C. Journal*, Vol. XV. No. 2. July, 1948.

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